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A Comparison of Performance on Measures of Executive Function and Metacognition in Normal Aging and Parkinson's Disease

by

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We accept this dissertation as conforming to the required standard

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ABSTRACT

This study was designed to inform theoretical and clinical understanding of the relation between executive function and metacognition in late adulthood, and to examine the effects of Parkinson's Disease (PD) on these aspects of the executive control system. The sample included two groups of neurologically intact (NI) participants and one group of participants with PD. All participants were over the age of 55 years and screened for dementia and depression. The NI young-old group included 22 participants between the ages of 56 and 74 years of age. A second group of 20 participants, between the ages of 75 and 90 years formed the NI old-old sample. The third group included 20 nondemented participants between the ages of 55 and 84 years with a diagnosis of PD.

First, on measures of executive function, memory, and motor performance significant age-related differences were limited. Tasks measuring the ability to generate novel concepts and to execute target motor movements revealed a significantly lower level of performance for the NI old-old participants, relative to their younger counterparts. While age-related differences in performance did not reach significance on the remaining tasks, the mean scores for the NI young-old group were slightly higher. The participants with PD had a lower level of performance than the NI groups in all three measured areas of functioning.

Second, the three measures of metacognition, performance predictions, postdictions, and questionnaire data each yielded distinctive results. The accuracy of predictions was largely resilient to the effects of aging. However, the prediction accuracy

of the PD participants was lower on measures of memory and gross motor performance. Groups were equivalent on measures of postdiction accuracy across measures, with the exception of the handwriting task where the NI groups showed a higher level of accuracy than the PD group. Perceptions of daily memory functioning were similar for the three groups. However, the participants with PD reported more motor problems than those reported by the NI groups.

Third, the results confirmed the theoretical relation between executive functioning and metacognition in the areas of memory and fine motor control, but executive function was found to have little impact on a more routine gross motor task. The relation between executive function and metacognition appears to be domain-specific, with a stronger association on cognitively-laden tasks relative to tasks of a more routine nature.

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To Garry, April, and Kory

Chapter I

Introduction

A Comparison of Performance on Measures of Executive Functioning and Metacognition in Normal Aging and Parkinson's Disease

Executive functioning is a multidimensional construct, theoretically including functions associated with planning and the effective implementation of goal directed behaviour (Stuss, 1987). The ability to monitor behaviour to correct errors or to compensate for discrepancies between environmental demands and ability level is an important element in determining the success or failure of the activity. As such, metacognition is a key element of the executive control system, which for the purposes of this paper will be defined as including executive functioning and metacognition, consistent with the model presented in the next chapter.

Research on the executive control system has primarily focused on changes occurring prior to the age of 75 years, with two independent lines of investigation. One line has examined cognitive change, identifying several aspects of executive functioning that begin to decline in late adulthood. The other line of investigation has restricted the parameters of study to thoroughly explore changes in metacognition, with the bulk of the research in the area of metamemory. The theoretical interaction of these two constructs of the executive control system suggests that the next step in the research process would be to examine how executive function and metacognition relate to one another. Specifically, do changes in executive function, as measured with neuropsychological instruments, influence metacognition such that deficits in executive function impair metacognitive performance? This research is designed to inform two areas of

psychological understanding. First, this study is designed to examine empirical support for the theoretical link between executive function and the superordinate role of metacognition. Second, this study will inform clinical understanding of how impairments in executive function could impact rehabilitation and the use of compensatory strategies.

The first component of this study investigates age-related changes in executive function in neurologically intact (NI), elderly adults. A study of adults under the age of 65 years has established areas of decline in executive functioning beginning in the fourth decade (Daigneault, Braun, & Whitaker, 1992). However, to expand understanding of developmental change associated with executive functioning it is necessary to determine whether age-related declines in executive functioning continue into old age. To examine this question, the performance of a group of NI young-old adults was compared with a similar group of old-old adults on neuropsychological tests of executive functioning. Research on aging has shown that declines in executive function are often correlated with deterioration of the frontal lobes and related subcortical structures (Moscovitch & Winocur, 1992). This study compared a group of participants with Parkinson's disease (PD), a disease typically associated with impaired executive function, with the group of neurologically intact participants to clarify whether changes in executive function related to metacognitive performance.

In contrast to the consistent findings of age-related declines in executive functioning, research investigating developmental changes in metacognition with adults under the age of 75 years has shown mixed results. The second component of this study focused on assessing two types of metacognition, awareness of memory and learning or

metamemory, and awareness of motor functioning. To increase the scope of this study methodological strategies were employed to measure both (a) systemic awareness, assessing general knowledge regarding memory and motor systems, and (b) on-line awareness, investigating the ability to monitor current performance in these areas (Cavanaugh, 1989). This component of the study investigated age-related change in various types of metacognition in NI elderly adults, and compared these results to the metacognitive abilities of people with PD. The goals were to determine whether factors of metacognition change consistently with age and how these changes are influenced by PD.

The third component of the study examined the relationship between executive functioning and metacognition with the twin goals of increasing the scientific and clinical understanding of the interaction of factors necessary for the effective implementation of goal directed behaviour.

The second chapter of this paper reviews the literature concerned with executive functioning and metacognition. First, studies examining age-related changes in executive function and metacognition are reviewed to provide an understanding of the empirical and theoretical foundations of this study. Second, research examining the effects of PD on these aspects of normal development are presented. The hypotheses of the study are outlined following the literature review.

The methods of investigation used in the study are the focus of the third chapter. Detailed descriptions of the sample, measures, and procedures are provided. Chapter four presents the results of the statistical analysis used to address the hypotheses of this study.

Finally, a discussion of the results in light of the current scientific literature is presented in chapter five.

Chapter II

Literature Review

The Executive Control System

The executive control system can be defined as a broad umbrella of abilities necessary for (a) volition or goal formulation, (b) concept formation and planning, (c) carrying out goal directed plans, and (d) effective performance (Lezak, 1995). In short, this system includes the ability to anticipate and establish goals, as well as the ability to self-monitor and regulate behaviour to achieve the desired goals (Stuss, 1987). As such, metacognition is an important aspect of the executive control system. While metacognitive processes have primarily focused on knowledge of the situational demand characteristics, and perceived behavioural outcomes involving memory (Hultsch, Hertzog, Dixon, & Davidson, 1988), the concept was expanded in this study to include the processes involved in executive function and motor tasks.

Anatomy of the executive control system. The executive control system is mediated primarily by frontal lobe structures. Frontal lobes are linked to most cortical and subcortical areas of the brain through a complex system of reciprocal connections, which leaves them vulnerable to the influence of global deficits, subcortical dysfunction, confusional states, and sleep deprivation (Stuss, 1993).

Many researchers contend that the frontal lobes have a common underlying function with domain-specific regions (e.g., Moscovitch & Winocur, 1992). Stuss (1987) postulates that the frontal lobes form an important basis for the primary components of executive function involving (a) sequence, set, and integration of material, and (b) drive,

motivation and will. The dorsolateral and lateral orbital areas of the frontal lobes are important for extracting information from a series and integrating it into the existing knowledge base to produce novel knowledge, while the midsagital areas of the frontal lobes are responsible for anticipating and establishing goals, planning goal attainment, and monitoring behaviour. More specifically, Kolb and Whishaw (1995) suggest that the dorsolateral prefrontal cortex is important for determining behaviours based on short term memories, while the inferior prefrontal cortex governs behaviour based on environmental cues. Connections between the frontal lobes, the brainstem reticular formation and the thalamus are believed to provide a mechanism for controlling conscious activity (Stuss & Benson, 1984).

Animal studies offer support for the involvement of domain-specific areas of the frontal lobes in executive tasks. Extensive work by Goldman-Rakic (1987) has shown that adult monkeys lesioned in the dorsolateral prefrontal cortex are unable to complete a delayed matching to sample task that requires recall of the sequence of events, integration of the sequence, and the ability to maintain a representation to determine the correct response. Single cell discharge studies have shown that in addition to neuronal involvement of the prefrontal cortex, neurons in the mediodorsal nucleus of the thalamus and in the caudate nucleus also fire during the delayed response task (Goldman-Rakic, Isseroff, Schwartz, & Bugbee, 1983). Lesions or surgical cooling of the head of the caudate in monkeys, sparing the dorsolateral prefrontal cortex, mimics the effects of lesions to the later area with subcortical sparing (Goldman-Rakic, 1987) highlighting the connections between cortical and subcortical structures.

Goldman-Rakic and colleagues (1983) cite extensive evidence of studies of aging humans and animals showing that the density, length, and arborization of specific groups of neurons diminishes with advanced age, with degradation mirroring the maturational process of development. Throughout human development neuronal loss in the prefrontal cortex, the subcortical structures of the basal ganglia, and the thalamus averages 20 percent between the ages of 20 and 80 years, while the percentage of neurons in other structures remains relatively stable (de Brabander, Kramers, & Uylings, 1998; Haug et al., 1983). The regional cortical volume of the prefrontal cortex, as measured with magnetic resonance imaging, declines significant with increasing age (Raz, Gunning-Dixon, Head, Dupuis, & Acker, 1998). More specifically, prefrontal grey matter showed the greatest reductions in volume relative to other areas of the brain (Raz et al., 1997). Despite these age-related structural changes, changes in the pattern of cerebral blood flow (CBF) appear to be subtle. Studies of positron emission tomography (PET) reviewed by Mitter (1988) present mixed results, with similar patterns of PET scans across age groups and limited declines noted with age. More recent research indicates that while the basic neurological patterns are maintained during aging, age-related changes are evident. For example, Schacter, Savage, Alpert, Rauch, and Albert (1996) found that the hippocampus is activated during memory retrieval in both young and old adults. However, in younger adults the anterior prefrontal cortex was also active during this task, while the posterior region of the prefrontal cortex was more active in older adults doing the same task. Similarly, while the same areas of the brain are activated in younger and older participants during a card sorting task, reductions in CBF in the prefrontal and parahippocampal

cortices are marked in the elderly participants, relative to their younger counterparts (Nagahama et al., 1997).

Generally, the research indicates that the prefrontal cortex and specific subcortical structures are the first to show the effects of age. In a study comparing young, HIV positive men with older, healthy men on a battery of neuropsychological tests, Hinkin and colleagues (1990) found that normal aging impairs the ability to carry out tasks of cognitive flexibility, verbal and nonverbal recall, and psychomotor speed. In other words, aging results in declining ability to perform many tasks commonly associated with the frontal-subcortical systems. Similarities in test patterns and the level of performance of the two groups led to the classification of the elderly men with the HIV positive group in a discriminant function analysis, suggesting that the two groups may have similar pathology of frontal and subcortical structures.

In a frequently cited study, Mittenberg, Seidenberg, O'Leary, and Digiulio (1989) concluded that changes in frontal lobe function was the primary component of cognitive impairment in the elderly. This conclusion was reached by comparing matched groups of young and old adults on a battery of tests designed to measure the independent abilities of both hemispheres equated on the dimensions of time pressure and familiarity. The results showed greater age-related declines on tests measuring frontal lobe function than on tests designed to measure temporal or parietal functions. Frontal lobe functions best discriminated the young and old groups and accounted for the most age-related change in performance.

Stuss and Benson (1984) state that patients with frontal lobe damage commonly show behaviours that can be seen as an inability to abstract information. For example, they may have problems translating knowledge of fact into action, problems shifting concepts and changing specific behaviour once it has been initiated, problems handling simultaneous sources of information, and a tendency to respond only to a fragment of the task or to the key features. Research to be reviewed later in this chapter will show that these problems are commonly seen in healthy, elderly adults, suggesting that the pattern of cognitive deficits associated with the normal aging process may be linked to deficits in the executive system. In turn, these deficits may have a negative impact on other functional systems, such as memory and movement.

When reviewing this research it is necessary to keep in mind that while the neuropsychological measures provide an indication of the functional integrity of the frontal lobes, all measures are also influenced by the integrity of other cortical and subcortical areas. Highlighting the fact that areas of the brain cannot be functionally isolated, research indicates that performance on the Wisconsin Card Sorting Test (WCST), a commonly used measure of executive function, is influenced as much by diffuse brain damage as it is by damage to the prefrontal cortex (Stuss, 1993). Nevertheless, the ambiguous problems presented by the WCST can be seen to approximate the continually shifting demands of life (Siris, 1991), while providing a quantifiable sample of behaviours that are associated with the conceptualization of executive functioning. In other words, while the neuropsychological measures used in the reviewed research may not produce

results that are dependent solely on the frontal lobes, they can be seen as a reflection of the behaviours associated with the executive control system.

Theoretical model of the executive control system. Stuss (1991a) presents a parsimonious model conceptualizing the hierarchical structure of interconnected components within the executive system. This model is composed of three major modules; (a) sensory and perception or basic knowledge, (b) supervisory or executive function, and (c) self-awareness and metacognition. Each module contains a mechanism for the input of information, which is then compared to the reference base for that module in the comparator subsystem and a response or output is generated.

For example, domain-specific sensory information or modality-specific knowledge from various brain regions provides input to the first module for analysis in relation to known facts in the comparator subsystem. The output provides the basis for routine or "automatic" behaviour which usually does not require frontal lobe involvement. The second module, associated with frontal cortical functions, is the supervisory or executive function module. This module receives the complex patterns generated by the comparator of the sensory module. The information is assessed according to principles of organization and judgement to integrate the ongoing activity of the domain-specific functions. The output is channelled through feedback loops to the sensory module, as well as forwarded to provide input to the third module of the system. The third module, dependent on the prefrontal region, is associated with self-awareness or metacognition. This module uses input from the sensory and the executive function modules in the form of abstract mental

representations which are compared to values and principles. The output feeds back to the executive module to modify and validate the behaviour.

While other comprehensive models define the relation between general cognitive and executive systems, (e.g., Baddeley, 1986; Norman & Shallice, 1986), there are two valuable aspects to the Stuss (1991a) model that are applicable to this study. First, this conceptualization dissociates the processes of executive function and metacognition. Each component in the hierarchical structure is conceptualized as receiving a broader range of increasingly integrated material which is channelled back to the preceding modules in a system of feedback loops. Hence, impairment in any one module should have an impact on the other modules in the system allowing for the possibility that dysfunction in each module, independent of the rest of the system, could result in different types of impairments. While impairment of the executive function module is likely to produce deficits in goal formulation and planning, dysfunction of the metacognitive module may impair the ability to spontaneously implement compensatory strategies to ameliorate the discrepancy between environmental demands and personal resources (Sohlberg, Mateer, & Stuss, 1993). Research to this point has focused on this dissociation, resulting in two independent lines of research. However, the feedback loops between the modules suggests that the modules are incontrovertibly linked, such that damage in one module will have an influence throughout the system. To increase our understanding of the executive control system, this study exams the links between the modules of executive function and metacognition.

Second, the Stuss (1991a) model provides a broad framework for understanding the mechanics of the executive control system, while allowing for the integration of other models to refine definitions. For example, Lezak's (1995) definitions of executive function, discussed at the beginning of this chapter, provide specific, testable concepts for the modules of executive function and metacognition. The module of executive function includes the abilities to formulate goals, form concepts and develop plans to carry out the goals, as well as the ability to implement the necessary behaviour to reach the desired goals. Effective performance, requiring self-monitoring of behaviour provides an operational definition for the metacognitive module. The remainder of this chapter will discuss the literature relating to the modules of executive function and metacognition as it pertains to normal aging and PD.

Aging studies

Executive functioning. Research shows that healthy, elderly adults have a variable developmental pattern of executive functioning, maintaining the ability to anticipate and set goals while developing deficits in the abilities necessary to form concepts and implement plans (for reviews see Cronin-Golomb, 1990; Moscovitch et al., 1992). The first component of Lezak's (1995) definition of the executive control system is volition or goal formulation. This is described as the motivation to determine appropriate needs and desires, contingent on an awareness of physical, social, and environmental factors, and the ability to extract and integrate relevant information. As there are few standardized measures of this aspect of executive function, assessment is typically limited to unstructured behavioural observations and interviews. Awareness of self in relation to

environmental situations can be addressed through questions addressing orientation to time and place, such as those found on the Mini-Mental State Examination (MMSE). Ceiling effects are typically obtained on these measures into advanced age, suggesting that the ability to formulate goals likely remains stable throughout much of the lifespan (Hopp, Dixon, Grut, & Bäckman, 1996; Tombaugh & McIntyre, 1992).

In contrast, deficits are apparent relatively early in the lifespan on tasks assessing the second component of Lezak's (1995) definition, concept formation and planning. The ability to plan strategies and to consider the alternatives available to reach the desired goal requires an understanding of environmental demands and current circumstances, as well as a conceptualization of the sequential behaviour that would likely produce goal attainment. These abilities are generally assessed by observing the method of approach to standardized tests. The number of categories achieved on the WCST is commonly used for assessing conceptual abilities. However, results must be interpreted with caution as it is difficult to determine the cause of low scores and results are confounded by high correlations with the number of perseverative responses and failures to maintain set (Beatty & Monson, 1990).

In a review of the literature, Cronin-Golomb (1990) concluded that the normal process of aging is generally related to problems with concept formation. She contends that deficits are particularly evident in age-related declines in performance on sorting tasks where it is necessary to develop guiding principles, such as the WCST. On the WCST, older adults usually show an increase in the number of errors (Axelrod, Jiron, & Henry, 1993; Boone, Miller, Lesser, Hill, & D'Elia, 1990), and a decrease in the number of conceptual level responses (Boone et al., 1990). Daigneault et al. (1992) found that adults

over the age of 45 years attain fewer categories on the WCST, and have difficulty with planning tasks, such as the Self-Ordered Pointing Test (SOPT) and Porteus Mazes, relative to younger adults. A similar pattern of performance is evident well into old age, with adults between the ages of 70 and 79 years continuing to show declining performance on these measures when compared with adults between the ages of 50 and 69 years (Boone et al., 1990). This research suggests that the abilities needed to form concepts and plan behaviours begins to decline early in the middle years of adulthood and continues into advanced age.

Research investigating age-related changes in the abilities necessary for effective plan implementation, the third component of Lezak's (1995) definition of executive functioning, has provided mixed results. Implementation of goal directed behaviour is supported by a broad spectrum of abilities of which cognitive flexibility, defined as the abilities required to consider alternative behaviours and shift response set, is of primary importance.

Eslinger and Grattan (1993) suggest that cognitive flexibility is in itself a multidimensional construct, with two identifiable forms, spontaneous and reactive flexibility. In this context, spontaneous flexibility is used to refer to abilities needed to generate a variety of responses to a given situation, at times requiring the suppression of habitual responses in favour of novel strategies. Eslinger and Grattan suggest that assessment of spontaneous flexibility would include such tests as verbal fluency and the Stroop test. Reactive flexibility, drawing on the ability to shift response set to meet changing environmental demands, can be measured through the use of sorting tasks, such

as WCST or the California Card Sorting Test (CCST). Comparing research participants with circumscribed lesions in the frontal lobes, the basal ganglia, or the posterior cortex with neurologically healthy control participants, Eslinger and Grattan found that those with lesions in the frontal lobes or the basal ganglia showed impaired reactive flexibility, while only the group with frontal lesions had impaired spontaneous flexibility. Structural magnetic resonance imaging has been used to show a direct association between age-related volumetric reductions in the prefrontal cortex and increased perseverative responses on the WCST (Raz et al., 1998). Similar findings were reported by Nagahama and colleagues (1997), showing a relation between increased perseverations on a modified WCST and reduced cerebral blood flow in specific areas of prefrontal and parahippocampal cortices in older adults. While these studies did not include a measure of spontaneous cognitive flexibility, and therefore cannot address the question of distinct neural substrates for separate aspects of cognitive flexibility, they provide an indication of the processes underlying age-related changes in reactive flexibility.

As people age it is common to find declines in spontaneous and reactive cognitive flexibility, evident in difficulty shifting concepts and changing behaviour once it has been initiated. On neuropsychological tests, age-related deficits of reactive flexibility may be seen as perseveration on the SOPT, WCST, and the Porteus Mazes (Axelrod et al., 1993; Daigneault et al., 1992) and problems shifting set on the Trail Making B task (Cronin-Golomb, 1990). When comparing the performance of participants under the age of 55 years with those over 55 years of age on measures of spatial memory, planning, and an attentional set-shifting task, Robbins and his colleagues (1998) found the greatest age-

related performance declines on the set-shifting task. Relative to younger adults, elderly people are also more likely to have reduced output on tasks demanding spontaneous cognitive flexibility. As such, performance on Design Fluency and the Stroop test typically declines with age (Dempster, 1992; Mittenberg et al., 1989). While verbal fluency is also considered to be a measure of spontaneous flexibility, and performance deficits have been related to specific frontal lobe areas (Baldo & Shimamura, 1998; Stuss et al., 1998), significant declines are typically not found in samples under the age of 80 years (Daigneault et al., 1992).

The complexity of the verbal fluency task may account for the differential pattern of age-related change, relative to other measures of spontaneous flexibility. The research reviewed to this point has identified verbal fluency as a unitary construct. However, Troyer, Moscovitch, and Winocur (1997) have shown that performance on the verbal fluency task depends on two dissociable components; the ability to cluster words into subcategories and the ability to switch between these clusters. On the phonemic fluency task, Troyer and her colleagues found that older and younger adults were equivalent on the number of words generated, and the number of times they switched between clusters. Older study participants generated more clusters than younger participants. On the semantic condition, cluster size was similar for both groups, with younger adults generating more words and switching between clusters more frequently. This study demonstrates the complexity of the verbal fluency measures, with each component differentially influenced by the effects of aging. Further research has shown that of these

two components, the ability to switch between clusters was found to be the most closely related to frontal lobe function (Troyer, Moscovitch, Winocur, Alexander, & Stuss, 1998).

While Cronin-Golomb (1990) suggests that the maintenance of verbal fluency into advanced age may be due to the over learned nature of verbal tasks, others contend that the general abilities related to executive functioning remain stable throughout adulthood. Boone, Miller, and Lesser (1993) suggest that research showing age related decline is generally contaminated by factors that are unrelated to measures of executive function, such as slowed processing speed, declines in visual and perceptual skills, and poorly screened samples (Boone et al., 1993). In support of their hypothesis, early research based on a carefully screened sample between the ages of 50 and 79 years failed to find significant differences in the performance on a verbal fluency task, perseveration on the WCST or in auditory trigrams, which require suppression of irrelevant information while recalling previously presented stimuli (Boone et al., 1990). In addition, Graf, Uttl, and Tuokko (1995), investigating a sample of healthy adults between the ages of 65 and 95 years, failed to find a direct path between age and interference effects on the Colour/Word Stroop test.

While some researchers (i.e., Baddeley, 1996; Shallice & Burgess, 1996) have recently argued that the executive control system is comprised of multiple components, each associated with a specific domain of functioning, others contend that the research supports a common substrate underlying many tests of executive function, with different tests measuring a unique aspect of the executive system (see Della Sala, Gray, Spinnler, & Trivelli, 1998 for a review). A factor analysis conducted by Boone, Ponton, Gorsuch,

Gonzalez, and Miller (1998) found that four measures of frontal lobe function, including WCST and verbal fluency, loaded on a common higher order factor in a sample of psychiatric inpatients, outpatients, and neurologically intact, middle-aged participants. Closer examination of the individual factor structure revealed that the WCST variables loaded on a factor primarily thought to represent "cognitive flexibility," and verbal fluency, the Stroop Test and Digit Symbol loaded on a factor reflecting "speeded processing." This research highlights the multidimensional structure of executive function (see Burgess, Alderman, Evans, Emslie, & Wilson, 1998), where executive function represents a diverse array of abilities, each of which is differentially influenced by related cognitive processes (Robbins et al., 1998).

In a similar line of investigation, Della Sala, Gray, Spinnler, and Trivelli (1998) found that the correlations among five tests of executive function, including tests of digit cancellation, figure-ground discrimination, sorting, mazes, and word fluency, were higher than the correlations between the "frontal tests" and five "non-frontal" tests. In a factor analysis of the executive function tests all five tests loaded on a single factor accounting for 53% of the variance. Expanding their factor analysis to include the "nonfrontal" tests, also resulted in the extraction of a single factor including 9 of the 10 tests and accounting for 45% of the variance, which likely represented general intelligence. The conclusions drawn from this study support the view that tests of executive function appear to tap a unitary construct. Further, the functioning of the executive system is a key component in many tests of non-frontal functions (Della Sala et al., 1998).

In summary, the research reviewed generally suggests that in daily life older adults are likely to have more problems regulating their behaviour in response to external stimuli, previous responses, and abstract concepts, as well as more difficulty planning complex behaviours than their younger counterparts. However, while further study is needed to provided a clearer understanding of how these complex constructs are influenced by age, as noted by Boone et al. (1993), it is important to carefully screen samples for medical and psychiatric illness, and to define the concept of executive function in order to draw useful conclusions from the research.

Finally, the fourth component of the executive control system, effective behaviour, depends on monitoring, self-correcting, and regulating qualitative aspects of behaviour such as tempo and intensity (Lezak, 1995). Research investigating developmental changes associated with event monitoring find age-related decrements in several areas. For example, age-related deficits in the ability to monitor temporal recency for verbal and nonverbal stimuli are commonly reported (Cronin-Golomb, 1990; Fabiani & Friedman, 1997; Kausler, Lichty, & Davis, 1985). In addition, relative to younger adults, older adults have problems monitoring the context of events (Spencer & Raz, 1994), as well as increased impairment in source memory (McIntyre & Craik, 1987). These deficits are particularly apparent when information is presented in a sequence of rapidly changing events (Schacter, Kaszniak, Kihlstrom, & Valdiserri, 1991). This pattern of results is similar to patients with frontal lobe damage, although the level of impairment in the elderly is not as extensive (Shimamura, Janowsky, & Squire, 1990).

Metacognition. Lezak's (1995) fourth component of executive functioning also incorporates aspects of metacognition that are necessary for comparing the present behaviour with a mental representation or a desired goal, determining strategies to reach the goal, and analysing the effects of the planned action (Stuss, 1987). In contrast to research showing age-related declines in the ability to monitor external stimuli, research investigating the ability of older adults to monitor general memory and on-line memory performance, compared with younger adults, is inconclusive. Brigham and Pressley (1988) taught matched groups of young and old adults the use of keyword and semantic recall strategies to facilitate recall of vocabulary lists. They found that the older group had more problems monitoring the effectiveness of the strategies than the younger group and were more likely to use the less effective semantic strategy than the keyword method. Although these results may be confounded by group differences in the ability to recall word-strategy associations, Brigham and Pressley concluded that the ability to monitor cognitive performance declines with age. This conclusion was supported by a study by Bruce, Coyne, and Botwinnick (1982) showing that younger adults were able to predict recall performance more accurately than older adults on a single trial, leading to the conclusion that age-related deficits in on-line monitoring are a normal part of the developmental process.

However, more recent work has shown that prediction accuracy is influenced by many factors, including recall performance and self-efficacy. Connor, Dunlosky, and Hertzog (1997) found that age-related differences in prediction accuracy on single-recall trial tasks can be ameliorated by improvements in recall performance. As older adults

typically over estimate recall performance, prediction accuracy improved when participants were instructed in the use of memory strategies to facilitate recall (Connor, Dunlosky, Hertzog, 1997). Rather than deficits in the ability to monitor on-line memory processes, single trial studies are likely providing an index of memory self-efficacy. Assessing the ability of older adults to monitor memory performance with prediction-postdiction studies over repeated trials has shown that predictions on the first trial are predominately determined by memory self-efficacy, while the ability to monitor memory performance is reflected in subsequent trials (Hertzog, Saylor, Fleece, & Dixon, 1994). As older adults became familiar with the tasks, over repeated trials, they are able to predict memory performance as accurately or more accurately than younger adults (Devolder, Brigham, & Pressley, 1990; Hertzog, Dixon, & Hultsch, 1990; McDonald-Miszczak, Hunter, & Hultsch, 1994).

Nevertheless, Connor, Dunlosky, and Hertzog (1997) have shown age-related differences in the pattern of prediction accuracy over repeated exposure to test materials, suggesting that the factors influencing metacognition may be differentially related to age. In this study, the prediction accuracy of older adults improved after they were provided with an opportunity to study the test materials, with subsequent postdictions reflecting the highest level of accuracy over the three phases. In contrast, the prediction accuracy of the younger adults declined from an accurate level on the prestudy prediction to an under prediction of performance after studying test materials. Postdiction accuracy for the younger participants was an accurate reflection of their performance.

Overall, research investigating age-related decrements in effective behaviour is mixed. While older adults appear to have problems monitoring environmental events, seen in age-related declines in source memory and temporal recency, their ability to monitor the cognitive process of memory appears to show little developmental decline.

Executive control system and memory. While patients with frontal lobe damage rarely have problems on pure memory tasks (Stuss, 1987), the animal studies of Goldman-Rakic (1987) have shown the importance of the connections between the prefrontal cortex and the hippocampal (explicit) memory system. Executive functions including temporal ordering, visual search, controlling interference effects, and the ability to use information in the desired manner are necessary for "working with memory", as termed by Moscovitch and Winocur (1992), and are specific to the prefrontal cortex. The explicit memory system relies on the executive system for determining input strategies to select information for attention, to organize and encode information for retrieval structure, to place information in context, and to conduct complex searches. As the research discussed above suggests, older adults show greater levels of impairment in these abilities when compared to younger samples, suggesting that age-related changes in the executive system may result in impairment on some memory tasks.

As people age they commonly show decline, when compared to younger adults, on word and text recall, which are dependent on self-initiated retrieval strategies, (Hertzog et al., 1990; Hertzog et al., 1994; McDonald-Miszczak et al., 1994), while recognition memory, with fewer cognitive demands, is relatively intact (Moscovitch et al., 1992). Viewed within the context of an aging executive system, recall performance could be

diminished as a result of several factors, including (a) inefficient encoding strategies, as older adults may be less likely to internally organize lists (i.e., deficits in concept formation and planning) than younger adults, and (b) a failure to encode information in the context of environmental cues (i.e., temporal ordering deficits) impairing ability to retrieve information. Decrements in processing resources, defined by Light (1991) as encompassing the capacity for attention and working memory, as well as speed of cognitive processing, offer a third possible explanation for age-related declines in memory recall. This would suggest that older adults may use strategies of encoding and retrieval less effectively than younger adults (Salthouse, 1991). Thus, age-related memory impairment could also be due to difficulties with the effective use of knowledge to guide goal-directed behaviour (i.e., deficits in effective plan implementation). Specifically assessing the role of executive processes on explicit memory function in healthy, elderly adults Troyer, Graves, and Cullum (1993) found that executive functions, reflected in measures of concept formation, the ability to inhibit a dominate response, semantic clustering, and perceptual organization, mediated the relationship between age and episodic memory. Partialling out the effects of executive functioning nullified the previously significant relationship between age and memory.

Executive control system and movement. Discussion of the executive control system to this point has been restricted to various aspects of cognitive abilities, however, executive functioning also plays an important role in the planning and execution of movement (Stuss et al., 1984). A brief anatomical review serves as a reminder that the motor cortex, responsible for the execution of movements, forms the posterior aspect of

the frontal lobes, while the selection of movements in response to external stimuli is primarily carried out by the prefrontal cortex (Kolb & Wishaw, 1995). As such, damage to the prefrontal cortex may produce an inability to plan, initiate and/or inhibit motor responses, as well as difficulty changing the motor response set (Stuss et al., 1984).

The literature reviewed above indicates that age-related change is apparent on many tasks of executive function requiring motor responses. Compared to their younger counterparts, older adults have more wrong entries and more perseverations on the Porteus Maze (Axelrod et al., 1993; Daigneault et al., 1992). Problems suppressing redundant information and changing response set can be seen in the age-related declines on the Trail Making Test B (Cronin-Golomb, 1990; Dempster, 1992). Further research is needed to investigate the impact of declines in executive function on awareness of motor performance.

Summary. Many of the tasks assessing the executive control system are thought to primarily measure functioning of the frontal lobes. The pattern of deficits and intact abilities outlined in the research suggests a dissociation within the executive control system, as it is represented by the Stuss (1991a) model, such that many components of executive functioning appear to be detrimentally influenced by the aging process, while the metacognitive component is largely spared. Two independent lines of research have developed to investigate age-related changes in the executive control system. One line of research has focused on changes in the abilities needed to formulate goals, to plan and develop concepts, and to regulate behaviour in response to environmental demands. In other words, this line of research has been concerned with the components of executive

functioning. The other line of research has focused on metacognition, or the ability to monitor, self-correct, and regulate performance. Further research is needed to join these two areas of research to produce a clearer picture of the relationship between metacognitive abilities, executive function, and the aging substrate.

Executive Control System and Idiopathic Parkinson's Disease

Idiopathic Parkinson's disease (PD) is a progressive, degenerative disease of the basal ganglia that is characterized as a movement disorder that includes symptoms of tremor, rigidity, postural abnormalities, and akinesia (slowness of movement). Early cognitive deficits, first apparent in behaviours associated with frontal lobe functioning, have also been recognized as a hallmark of the disease (Cummings & Benson, 1988). Typical age of onset is after the age of 40 years, with the majority of cases not developing until the fifth or sixth decade. Thus, the developmental losses associated with aging are likely to be exacerbated by the effects of PD. People who are afflicted with PD later in life have higher levels of cognitive impairment on tests of visuospatial ability, verbal memory, and executive function (Katzen, Levin, & Llabre, 1998), and show more severe gait disorders, and postural instability (Agid, 1991).

Pathophysiology of PD. Dopaminergic deficits are a primary diagnostic feature of PD (Agid, 1991; see Lang & Lozano, 1998 for review). The nigrostriatal dopaminergic pathway is severely impaired by the disease, with the neurons projecting from the pars compacta of the substantia nigra to the putamen (motor striatal area) showing greater deficits (85-97.8%) than the neurons projecting to the cognitive striatal area of the caudate (75-81.5%: Agid, 1991; Hornykiewicz, 1998). Less neuronal loss is found in

other dopaminergic pathways, such as those projecting to the hypothalamus, and in the mesocorticolimbic pathway which projects from substantia nigra and the ventral tegmental area to the lateral and medial prefrontal cortex, including the limbic system. In normal aging, cell loss in the substantia nigra is slightly less than 50% at the age of 80 years, maintaining an asymptomatic level of function, compared to declines of approximately 60% at age of onset of idiopathic PD (Agid, 1991) and over 80% in advanced stages of PD (Hornykiewicz, 1998).

While dopaminergic deficits show the greatest decline with PD, other neuronal systems showing progressive deterioration include (a) the noradringeric system from the locus coeruleus with decreases of 20% to 60% in the frontal lobes, the cingulate gyrus, entorhinal cortex, nucleus accumbens, amygdala, locus coeruleus, and the hippocampus; (b) the cholinergic system with the marker of choline acetyltransferase originating in the nucleus basalis of meynert; and (c) the serotoninergic system originating in the raphe nucleus (Agid, 1991; Cummings, 1988; Lang & Lozano, 1998). Each of these neuronal systems has projections to the cortex and the limbic system. The presence of Lewy bodies, in addition to neuronal loss with depigmentation in the pars compacta of the substantia nigra, is also found in the majority of people with PD (Agid, 1991; Litvan et al., 1998). Nevertheless, as Lewy bodies are present in other neurodegenerative disorders they are not considered to be a biological marker for PD (Lang & Lozano, 1998).

Theoretical model of PD. Anatomically, the frontal lobes and subcortical structures are closely connected. In adult monkeys, damage to the dorsolateral cortex produces impairment on delayed matching to sample tasks, which can be reproduced by

lesions restricted to the subcortical structures of the caudate nucleus and the dorsomedial thalamus (Goldman-Rakic, 1979). PET studies of PD patients show a mild diffuse reduction in metabolism of both the cortical and the subcortical structures compared to normal elderly (Cummings et al., 1988). The frontal caudate "complex loop" hypothesis first proposed by Delong and Georgepoulos (1981) contends that the widespread projections of the cortex form a complex loop that passes through the caudate to the anteroventral nuclei of the thalamus, which relays the information back to the anterior cingulate, the dorsolateral prefrontal cortex, and the lateral orbitofrontal cortex, areas of importance for accomplishing delayed response tasks in monkeys (Goldman-Rakic et al., 1983). As PD results in dopamine depletion in the prefrontal cortex and the caudate, this caudate outflow model provides a possible explanation of how the additive effect of these deficits could produce the wide range of cognitive impairment found in PD. However, it must be recognized that PD is a heterogenous disorder with variability between patients depending on the location, size, and order of lesion development (Agid, 1991), and as such a single model cannot fully explain all of the deficits exhibited by PD patients.

As predicted by this model, impairment is typically seen on tasks involving executive functioning, such as problems maintaining and shifting set, the inhibition of one response while activating another, impairment on the use of internal organization and cues, and slowed movement with increased task complexity (Bondi & Tröster, 1997; Dubois, Boller, Pillon, & Agid, 1991; Dubois & Pillon, 1997). A similarity in the nature of memory impairment between PD and Huntington's disease, both related to degeneration of the basal ganglia, suggests that impairment of subcortical structures influences patterns of

cognitive function (Massman, Delis, Butters, Levin, & Salmon, 1990). More specifically, within the basal ganglia, memory impairment has been linked to dopamine deficiencies in the caudate nucleus in patients with PD (Holthoff-Detto et al., 1997). In addition, many of the cognitive deficits found in PD are similar to those seen in patients with frontal lobe damage, resulting in impairment in excess of that associated with normal aging.

Executive functioning. Age, duration of illness, and severity of symptoms are independent correlates of cognitive dysfunction in PD, with the risk of severe cognitive impairment the greatest for those over the age of 70 years (Cummings, 1988; Stern, Marder, Xi Tang, & Mayeux, 1993). Mayeux and colleagues (1990) found that the incidence of dementia in idiopathic PD is at the highest levels between ages 65 to 75 years, with an increased frequency of dementia in PD patients compared to normal elderly. Over the duration of PD the probability of dementia increases in frequency and the symptoms of dementia become more severe to the point of affecting survival. Pathophysiological findings indicate that the density of Lewy bodies in the CA2 area of the hippocampus may determine the severity of cognitive impairment in PD patients with dementia (Churchyard & Lees, 1997). As a measure of the behavioural severity of PD, extrapyramidal signs of postural instability, gait and bradykinesia have a significant relationship with cognitive abilities (Richards, Stern, Marder, Cote, & Mayeux, 1993), suggesting that cognitive deficits are also at least partly the result of dopamine deficiency. Levodopa treatment, implemented to increase the systemic level of dopamine, initially improves cognitive abilities, although seldom to normal levels and declines persist with disease progression (Cummings, 1988). Recent research has shown that the dopaminergic system plays an

important role in set-shifting abilities (Tamaru, 1997), and in maintaining a variety of cognitive processes (Rogers et al., 1998). Patients withdrawn from dopaminergic medication show increased impairment on frontal lobe tasks, like the Tower of London and spatial span, but not on tasks of learning and memory (Lange et al., 1992).

This dissociation, between tasks that are influenced by dopamine deficiency and those that are not, indicates that dopaminergic deficits are not the sole cause of cognitive impairment in PD. Dubois, Pillon, Lhermitte, and Agid (1990) compared PD patients on anticholinergic medication with a matched group of patients on alternative forms of medication. They found that while anticholinergic medication did not impair memory or instrumental abilities it increased deficits on tasks measuring frontal lobe functions, suggesting that cholinergic deficits may also play an important role in executive abilities.

The heterogeneity of PD produces a variable pattern of disorders within the categories conceptualizing executive function. Typically, across studies deficits are found on tasks that require the use of internal strategies, self-generated responses, and other forms of mental effort, suggesting that the deficits in cognitive abilities may be due to dysfunction in the executive control system (for review see Brown & Marsden, 1990; Dubois et al., 1991; Dubois & Pillon, 1997; Mayeux, 1990; Raskin, Borod, & Tweedy, 1990). As PD patients are typically of advanced age it is reasonable to assume that the detrimental effects of the disease and the deficits of the executive control system associated with the normal developmental process of aging will be additive, leading to the hypothesis that PD patients will show deficits similar to those of their healthy contemporaries in some areas and increased deficits in others. The following review will

focus on the performance of nondemented PD patients on the components of executive functioning; (a) goal formulation, (b) concept formation and planning, (c) effective plan implementation, and (d) self-regulation.

As discussed earlier, the first component of executive functioning defined by Lezak (1995) is volition, including the ability to formulate goals, maintain awareness of physical status, social demands, environmental factors, and self-motivation. While research in this area is very limited, in disease-free adult development the abilities required for goal formulation generally remain stable through to advanced age. In contrast, PD is detrimental to this process, often resulting in (a) reduced orientation to time and place relative to healthy cohort members (Richards et al., 1993), and (b) apathy, stemming from subcortical dysfunction, a hallmark of PD disease (Cummings et al., 1988).

Research examining Lezak's second component of executive functioning, concept formation and planning, shows that the ability of PD patients to conceptualize and consider various behavioural options while planning goal-directed behaviour varies with the type of task assessed. Compared to age matched controls, PD patients have problems constructing the sequences of behaviour necessary to complete tasks such as the Tower of London (Cummings et al., 1988). In a pattern typically associated with PD, patients are capable of solving the three-disk Tower of London problem, but they take longer to complete the first move than others of a similar age. Impairment becomes evident when the degree of complexity is increased, as in the four-disk version of the Tower of London (Dubois et al., 1991). These results cannot be completely accounted for by bradyphrenia as PD patients may be slower at developing a plan, but capable of carrying out the plan at

normal speeds (Brown et al., 1990). Rather, they suggest a difficulty organizing and planning the requirements of the task that reaches a level of severe disability as the complexity of the task increases. Deficits in planning are also apparent with the failure of PD patients to (a) improve with practice on a task where subjects were required to trace lines with deleted segments, drawing on planning and sequencing skills (Raskin et al., 1990), (b) show an increased rate of errors as this task became more complex (Raskin et al., 1990), and (c) use internal memory strategies on immediate recall tasks (Massman et al., 1990; Taylor, Saint-Cyr, & Lang, 1990).

Similarly, difficulties are also found on tests measuring the ability to form concepts such as tasks of verbal fluency for categories (semantic conditions), while performance on tests of letter fluency (phonemic conditions) is maintained (Beatty, Staton, Weir, Monson, & Whitaker, 1989; Raskin, Sliwinski, & Borod, 1992). Although performance levels comparable to that of an age-matched control group has also been reported (Troyer, Moscovitch, Winocur, Leach, & Freedman, 1998). In summary, PD patients show deficits on many tasks of concept formation and planning that require internal, active and effort demanding strategies, or spontaneous task-specific solutions (Brown et al., 1990).

In the normal elderly population, research has documented deficits in abilities related to effective plan implementation, the third aspect in Lezak's definition of executive function, such as cognitive flexibility. PD further exacerbates these declines, with PD patients showing increased levels of impairment on many tasks relative to age matched controls. Examples include (a) a reduced ability to maintain and shift mental set, as measured by the WCST and Odd-Man-Out test (Monza et al., 1998), with evidence of

increased perseveration (Brown et al., 1990; Cummings, 1988) and slowed response times in excess of that in seen same set responses when set-shifting was required (Hayes, Davidson, Keele, & Rafal, 1998), (b) deficits in visuomotor sequencing and set shifting, such as those measured with the Trail Making Test B and sequential movements tests (Monza et al., 1998; Raskin et al., 1990; Tamaru, 1997), and (c) an impaired ability to screen out interference as measured by the Stroop-like tasks (Cummings et al., 1988; Hayes et al., 1998) and the Conditional Associative Learning Test (CALT: Taylor et al., 1990). These tasks require the regulation of behaviour based on a conceptualization of task demands, which is problematic for PD patients, particularly those experiencing deficits in other areas of cognitive functioning (Beatty et al., 1990).

The executive ability of effective behaviour, Lezak's fourth component of executive function, is accomplished through monitoring and self-correcting each component in the executive process, that is (a) goal formulation, (b) concept formation and planning, and (c) the implementation of goal directed plans. Inadequate monitoring or self-correcting mechanisms will result in behavioural impairment given an error in the completion of any component in the executive process. The ability of PD patients to monitor their environment is impaired relative to their healthy peers, as evidenced by impairment on tasks of temporal ordering, and recency discrimination (Brown et al., 1990; Dubois & Pillon, 1997; Vriezen & Moscovitch, 1990). Relative to normal controls, newly diagnosed PD patients also exhibit deficits in source memory (Taylor et al., 1990), independent of their ability to carry out simple tasks of memory scanning (Lafleche, Stuss, Nelson, & Picton, 1990).

Metacognition. In contrast to the body of research investigating the ability of PD patients to monitor external aspects of behaviour, metacognition in PD has received little research attention. Brown, MacCarthy, Jahanshahi, and Marsden (1989) investigated the accuracy of a self-report measure on the impact of parkinsonian symptoms on the ability to carry-out activities of daily living (ADL). Questionnaires were completed by people with various levels of disability due to parkinsonism, with a corroborating completed by one of their relatives. In addition, independent ratings on the patients' ability to complete ADLs was assessed by an independent observer. The results showed a high level of agreement between the raters. Comorbid indicators of cognitive impairment and depression had little influence on the patients' reports. This study suggests that patients with parkinsonian symptoms can accurately judge their ability to complete common daily activities.

Nevertheless, general cognitive impairment has been reported to be related to impaired metacognitive abilities (Burgess et al., 1998). In the Burgess study, questionnaires regarding common problems associated with executive dysfunction in daily life were completed by study participants and by people who were familiar with participants. While participants in the neurologically intact group reported more problems relative to the report of their familiar counterpart, the neurologically impaired group reported fewer and less severe symptoms than those reported by their caregivers, despite lower scores on most tests of executive function than those achieved by the control group. This research supports Stuss' (1991a) conclusions that impaired metacognition can be the result of disturbances in frontal lobe function.

Investigations of the ability to self-monitor motor performance is a relatively new area of research. One of the few studies conducted found that patients with Huntington's Disease (HD) had little understanding of how their movement disorder generally affected their ability to perform cognitive and motor tasks commonly required in daily activities, while they were able to accurately predict their ability to carry out specific tasks, such as word pronunciation and walking a straight line (McGlynn & Kaszniak, 1991). Two important implications from this study are (a) awareness of performance is multifactorial, with questionnaire data measuring systemic awareness producing different results than prediction data measuring on-line awareness, and (b) the ability to self-monitor performance may not be domain specific, as no differences were found between cognitive and motor tasks (McGlynn et al., 1991). As this study employed a small sample size (n = 8) of patients with HD, several of whom were moderately demented, and a broad age range (22 to 68 years) further research in this area is warranted.

In summary, the research reviewed indicates that PD patients experience deficits in several areas of the executive control system relative to their peers. In daily life, deficits of this nature may present as (a) a rigid approach to problem solving and responses to environmental demands (Lezak, 1995), (b) deficits in memory and visuospatial functions (Cummings, 1988), and (c) an impaired ability to understand complex language structure (i.e., involving categorization or relationships in complex sentence structures; Grossman, Carvell, Stern, Gollomp, & Hurtig, 1992). As the executive system serves a tertiary function, the additive effect of executive dysfunction is likely to be evident in functional systems, such as memory and motor abilities.

Executive control system and memory. Memory deficits in PD are typically found on tasks that require internal control or integration (Brown et al., 1990; Raskin et al., 1990), in other words, tasks mediated by the frontal lobes (Stuss, 1991b). For example, recognition memory for verbal, nonverbal, abstract and concrete items, as well as immediate verbal memory for information that is currently in attention, such as digit span, is preserved (Flowers, Pearce, & Pearce, 1984). In contrast, PD patients show poorer performances on tests of attention to visual stimuli (Monza et al., 1998), and memory ability is generally impaired in conditions introducing an interference task, as in the case of the consonant trigram task, or if a self-generated response is required (Dubois et al., 1991; see Dubois & Pillon, 1998, for a review). Sullivan, Sagar, Cooper, and Jordan (1993) report that recently diagnosed and medicated PD patients had near perfect immediate verbal recall in distracter-free conditions, but were impaired in a distracter-filled condition compared to matched controls. The spontaneous decay of nonverbal information in the distracter-free condition precluded further decline in the distracter-filled condition. The results suggest that short-term memory deficits for nonverbal information may be more severe than for verbal recall, and the deficits are likely due to the disease pathology, rather than as a side effect of treatment. PD patients may also have difficulty with delayed response tasks, similar to those found in humans with prefrontal lesions, and in monkeys with dorsolateral prefrontal lesions (Dubois et al., 1991; Raskin et al., 1990). Delayed response tasks draw on an internal representation of the task to guide behaviour (Goldman-Rakic et al., 1983), thus, deficits on this task could be due to problems

maintaining the representation of the object while screening out competing stimuli or in self-regulation of behaviour.

The severity of the disease appears to be an important factor in determining word list recall performance. Beatty et al. (1989) found that patients in advanced stages of PD had impaired word list recall, but the relatively automatic process of multiple choice recognition memory was intact compared to age-matched controls. In contrast, Taylor and colleagues (1990) found that in newly diagnosed patients in the early stages of PD word list recall was only impaired relative to normal controls when the use of strategies could have facilitated immediate recall. In long-term recall, which is facilitated by the hippocampus, the PD patients organized the word list by categories as efficiently as the control group, suggesting that PD affects the early stages of memory without impeding the consolidation of memories necessary for normal processing. As the disease progresses, more explicit organization of long-term memory may also be required.

Memory impairment associated with PD is specific, with dissociations between tasks requiring effortful processing showing impairment, while those only depending on recognition of items from a multiple choice array generally found to be intact (Brown et al., 1990). This suggests that PD patients have the ability to register, store, and consolidate information but that they have problems with the functional use of memory, dependent on the frontal lobes.

As a tertiary level of processing with anatomical and theoretical links to other cortical and subcortical structures, executive dysfunctions are often presented as specific impairments. For example, PD is typically associated with deficits in visuoperception and

visuoconstruction skills, in addition to specific memory impairments. However, Bondi, Kaszniak, Bayles, and Vance (1993) found that once the variance associated with performance on the modified WCST, CCST, a generative naming task, and a verbal temporal order task was statistically covaried, the deficits of PD patients compared to healthy controls were not significant. In contrast, the groups remained statistically distinct on measures of frontal lobe functioning after the variance associated with nonfrontal tasks was removed. This finding supports the "complex loop" hypothesis that many of the cognitive deficits exhibited by PD patients are the result of dopamine deficiency in the frontal lobes, leading to the impairment of the executive system.

Executive control system and movement. As with normal aging, problems with concept formation and planning, the ability to carry-out goal directed behaviour, and effective performance can be expected to influence motor behaviours in people with PD. Nevertheless, the interpretation of performance on motor tasks believed to measure executive function in this population may be difficult to establish, as extrapyramidal impairments are a hallmark of this disease. As reviewed earlier, PD patients have problems organizing and planning the requirements of complex motor tasks in excess of those attributed to age or the reduced speed of cognitive processing and task completion attributed to the disease. These deficits are apparent on the four-disk version of the Tower of London (Dubois et al., 1991), and motor sequencing tasks (Raskin et al, 1990). The effects of PD also exacerbate age-related deficits on tasks requiring the self-regulation of behaviour and cognitive flexibility, such as deficits in visuomotor sequencing and set

shifting in Trail Making B (Raskin et al., 1990). Investigations of the ability to self-monitor motor performance requires further research attention.

Summary

In the normal aging process, the prefrontal cortex shows the first signs of age, with a higher proportion of dendritic loss than other cortical areas, and reduced rCBF (Haug et al., 1983). Impairment of the substrate subserving the executive system due to normal aging presents the possibility that these changes may be contributing factors in the declines related to the normal developmental trajectory of the executive system. In turn, deficits in executive function may affect domain-specific functional systems in the posterior brain regions.

Research indicates that the executive system of PD patients is further impaired, possibly due to the additive effect of reduced levels of dopamine and cholinergic neurotransmitters, and the physiological correlates of normal aging. PD patients generally have difficulty (a) establishing the necessary motivation to form goals, (b) on many aspects of concept formation and planning, (c) on tasks requiring flexibility of cognition and perception, and (d) with effective regulation of behaviour. In many areas, the pattern of deficits is the same as that of normal elderly adults, although the magnitude of deficits is greater. In other areas, particularly those with fewer demands on the executive system, PD patients show the same level of performance as their healthy peers. It is difficult to separate the confound of age and PD. In an attempt to disentangle these variables, this study proposes to first examine the effects of age-related change in executive functioning

and metacognition, then compare these results with the performance of age peers with PD.

Goals of the study.

This study has three main goals. The first goal is to examine age-related changes in the executive functioning of neurologically intact (NI) elderly adults by comparing the performance of young-old and old-old participants, and to contrast the normal development of executive functioning with the changes occurring in conjunction with PD. In general, it is expected that NI older adults will perform more poorly on neuropsychological measures of executive function than their NI young-old counterparts. Further, participants with PD are expected to have a lower level of performance on these measures than NI participants. Specifically, on the task of verbal fluency the NI old-old participants are expected to produce fewer words beginning with the target letters or category than NI young-old participants. Participants with PD are expected to produce fewer correct responses, particularly for the target category, than the NI participants. Similarly, the modified California Card Sorting Test is expected to reveal age-related decrements in performance with NI old-old adults producing more perseverative responses and fewer accurate sorts than the comparison group of NI young-old participants. Participants with PD are expected to show a greater level of impairment on these measures than the NI participants. The expected pattern of performance on the recency discrimination task is similar to those outlined above, with NI old-old participants producing more errors in word list order on the recency measure than the NI young-old group. The performance of those with PD is expected to more impaired than that of their NI counterparts.

Assessing age-related differences in metacognition related to memory and motor performance, and contrasting this with the changes associated with PD is the second goal of the study. To date, research has focused on age-related differences in the performance of young and young-old participants on metacognitive tasks. This literature suggests that awareness and knowledge of memory performance remains constant or improves with age. However, given age-related decrements in executive functioning and an extension of the developmental time line to include old-old participants, this study expected to show that young-old, NI participants have higher levels of pre/postdiction accuracy than their old-old counterparts. Further, the accuracy levels in both groups are expected to increase across trials on memory and motor tasks. On the basis of the pathology associated with PD, it is expected that the pre/postdiction accuracy of the participants with PD will show greater impairment on these measures than the NI controls. In addition, it is expected that the group with PD will improve to a lesser degree over trials of memory and motor tasks than the control group.

The third goal of the study is to determine the relationship between executive function and metacognition, as it relates to memory and motor performance. Specifically, this study will investigate whether the measured aspects of executive function are related to the level of performance awareness and knowledge exhibited by NI elderly adults and those with PD. Theoretically, impairments in executive function are expected to result in reduced awareness of performance ability. As the literature suggests that decrements in executive function increase with age it is expected that the reported performance accuracy of NI old-old adults will be lower than their young-old counterparts. Further, with

impairments in several areas of the executive system associated with PD it is expected that the accuracy of performance reports will be the most impaired for participants with PD. Although questionnaire data theoretically assess systemic awareness, while pre/postdiction performance provides a measure of on-line awareness, the pattern of results is expected to remain constant across the two measures, although the degree of awareness reported by each measure may differ.

Chapter III

Methods

Participants

Seventy-two residents of southern Vancouver Island volunteered to participate in this study. The neurologically intact participants were solicited from a pre-existing subject pool. The participants with PD were recruited through the use of a letter given to all patients with PD by their neurologist. A brief screening questionnaire was administered to the participant at the beginning of the session to obtain (a) demographic information, (b) medical history influencing cognitive functioning including neurological or psychiatric disorders, alcohol use, learning disabilities, or current major memory complaints, and (c) self-rating of current health. Participants were asked to rate their health on a 4-point scale (1= excellent, 2 = good, 3 = fair, 4 = poor) compared to others their own age. Self-ratings have been shown to correlate highly with physician's ratings following a medical examination (LaRue, Bank, Jarvik, & Hetland, 1979). Inclusion in the study required that participants must be 55 years of age or over, nondemented (scoring ≥ 25 on the MMSE), and not depressed (scoring < 11 on the Geriatric Depression Scale: GDS). In addition, PD patients required (a) a medical history with a diagnosis of idiopathic PD that had been confirmed by a neurologist, and (b) a disability rating staged at not greater than stage 3 on the Hoehn and Yahr scale (Hoehn & Yahr, 1967), indicating a mild to moderate level of disability. Three neurologically intact (NI) volunteers and five volunteers with PD were excluded from the study due to scores above 10 on the GDS. One person with PD who was under the age of 55 years and one NI old-old person who scored below the MMSE

cut-off were also excluded. The remaining 62 participants formed three groups, with the sample characteristics presented in Table 1. The NI young-old sample was composed of 22 participants between 56 and 74 years of age. A similar group of 20 participants, between the ages of 75 and 90 years formed the NI old-old sample. The Parkinson's group included 20 nondemented participants between the ages of 55 and 84 years with a diagnosis of PD. Of the participants diagnosed with PD, only 18 were able to identify the duration of their diagnosis, which ranged from .07 to 12 years ($M = 5.59$, $SD = 4.44$). The severity ratings of Parkinsonian features were limited to the mild to middle stages as defined by Hoehn and Yahr (1967: Stage I: $n = 10$; Stage II: $n = 9$; and Stage III: $n = 1$). Medication used at the time of testing included pergolide ($n = 2$) a dopamine agonist, and levo-dopa ($n = 19$) a dopamine precursor. Three participants were also taking an enzyme (catechol-o-methyl transferase) inhibitor as part of a PD drug study, and one participant was not taking medication. A Pearson product moment correlation between the time of day testing was conducted and increased severity of motor problems failed to reveal a significant relation within the PD group, $r = -.13$, $p = .58$.

Table 1

Sample Characteristics

Sample	n	Age (M Years)	MMSE	Gender (F:M)	Education (M Years)
NI Young-Old	22	67.46	28.73	10:12	15.77
(SD)		(5.77)	(.83)		(3.95)
NI Old-Old	20	80.00	28.30	11:9	14.45
(SD)		(3.52)	(1.03)		(3.25)
Parkinson's	20	72.50	27.45	7:13	13.90
SD		(7.61)	(1.61)		(2.27)
Combined NI	42	73.43	28.52	21:21	15.14
(SD)		(7.94)	(.94)		(3.65)

Note. MMSE = Mini Mental State Exam.

Analyses were conducted to determine the equivalency of age, MMSE, and education across groups. A one-way between-subjects analysis of variance (ANOVA) comparing the three groups with age as the dependent variable showed a significant effect, $F(2,59) = 24.08$, $p < .001$, $\eta^2 = .45$. Post hoc comparisons, with a Bonferroni correction establishing alpha at .017 to protect against Type I error, found that the effect of age was accounted for by a significant difference between the NI young-old and the NI old-old participants, Tukey HSD = 12.55, $p < .001$, as well as a significant difference between the NI old-old and the PD participants, Tukey HSD = -7.50, $p = .001$. The mean ages of the NI young-old and the PD participants were substantially different, although not significant given the correction, Tukey HSD = 5.05, $p = .02$. A one-way ANOVA comparing the

combined NI group with the PD group on age also failed to show a significant effect, $F(1,60) = .19$, $p = .66$. As seen in Table 1, the participants in the NI old-old group were older than the NI young-old participants and those in the PD group.

To compare the groups on the dependent variable of MMSE total score, a one-way between-subjects ANOVA was conducted. Findings indicated that the total MMSE scores were significantly different across groups, $F(2,59) = 6.19$, $p = .004$, $\eta^2 = .17$. Post hoc comparisons, with a Bonferroni correction establishing alpha at .017, found the NI young-old group scored significantly higher than did the PD group, Tukey's HSD = -1.28, $p = .003$. Comparisons of the NI old-old group with the NI young-old and the PD groups did not reveal significantly different MMSE scores. A one-way ANOVA comparing the MMSE scores of the combined NI group with the PD group found the NI group scored significantly higher, $F(1,60) = 10.97$, $p = .002$, $\eta^2 = .16$. However, all mean values were within the normal range, and no participant scored below 25.

Between-subjects ANOVAs comparing the scores of the three participant groups were conducted separately for each of the conceptual groupings of items on the MMSE. Results indicated a significant difference in group scores only on the question measuring recall memory, $F(2,59) = 3.22$, $p = .047$, $\eta^2 = .10$. Group scores were not significantly different on orientation, attention, or language, $F(2,59) \leq 1.58$, $p > .05$. Analysis could not be conducted on the registration item due to a lack of variability on this measure.

A one-way between-subjects ANOVA conducted to assess equivalence of self-reported ratings of depressive symptoms across the three groups, with the scores on the GDS as the dependent variable, showed that GDS scores were significantly related to

group membership, $F(2,59) = 6.56$, $p = .003$, $\eta^2 = .18$. While the participants in the PD group did not score in the clinically depressed range (i.e., GDS > 10) they reported a greater number of symptoms commonly related to depression ($M = 6.45$, $SD = 3.02$) than did the combined NI group ($M = 3.81$, $SD = 2.84$).

A one-way between-subjects ANOVA showed that the level of education was similar across groups, $F(2,59) = 1.85$, $p = .167$. A one-way ANOVA with self-rating of health relative to age peers as the dependent variable did not show a significant group effect, $F(2,59) = 2.69$, $p = .077$. To analyse group differences on the self-report measures of specific health conditions a multivariate analysis of variance (MANOVA) was conducted with 11 of the 12 questions. The question regarding diagnosis of PD was omitted. Reported health problems were not found to be significantly different between the groups using the Wilks' criterion, $F(22,98) = .85$, $p = .66$.

Measures

Mini-Mental State Exam. The Mini-Mental State Exam (MMSE: Folstein, Folstein, & McHugh, 1975) is a well-established brief screening measure of cognitive functioning, assessing orientation, attention/concentration, memory, praxis, and language. The MMSE includes 11 questions, scored on a scale from 0 (lowest) to 30 (highest level of cognitive function). A cut-off score of 25 was used in this study, with those scoring 25 or more classed as nondemented (O'Connor et al., 1989). In a community sample of elderly adults, this cut-off point had a sensitivity of 98% (percent accurately classified as demented), and a specificity of 89% (percent accurately classified as healthy; O'Connor et al., 1989). The coefficient alpha in a sample of very old, highly educated adults ranged

from .31 to .52 across multiple testing occasions (Hopp et al., 1996), reflecting the multi-dimensional nature of the test. Test-retest correlations in community samples of healthy elderly adults have been reported between $r = .56$ to $r = .80$ for six months (Hopp et al., 1996), and one-year correlations ranged from $r = .23$ (Olin & Zelinski, 1991) to $r = .50$ (Mitrushina & Satz, 1991). The reliability of this measure improves with the use of standardized procedures (Olin & Zelinski, 1991).

The MMSE was administered as directed in the original paper (Folstein et al., 1975), with the exception that participants were asked to spell "WORLD" backwards, in place of serial sevens, to increase standardization of the procedures (Olin & Zelinski, 1991). The necessity of obtaining multiple measures within a brief period of time to avoid overtaxing participants was accommodated by the brief nature of the MMSE, which took between 5 and 10 minutes to administer.

Geriatric Depression Scale. The Geriatric Depression Scale (GDS: Yesavage et al., 1983) was used as a screening measure for mood. The GDS is a well-established measure for the assessment of depression in the elderly, including those who are physically ill (Yesavage, 1987). This measure is composed of 30 yes/no questions (e.g., "Are you basically satisfied with your life?") assessing mood and activity level, with an established cut-off score for normal mood. In hospitalized patients, a cut-off score of greater than 10 has a reported sensitivity of 92%, a specificity of 89%, and a negative predictive value of 99% (Yesavage, 1987). Cronbach's alpha has been estimated at .94, showing high internal consistency, with a one-week test-retest reliability correlation of $r = .85$ (Koenig,

Meador, Cohen, & Blazer, 1988). The GDS was administered orally and was completed within five to ten minutes.

Verbal fluency tasks. The verbal fluency tasks, extracted from the Neurosensory Centre Comprehensive Examination for Aphasia (Spreen & Benton, 1977), assess the speeded production of phonemic and semantic information, drawing on organizational skills and necessitating self-monitoring for effective performance. Two measures of verbal fluency were administered; (a) letters (F, A, and S) and (b) semantic category (animals). Participants were given one minute to complete each task component. The performance score was calculated as the sum of all words matching the target category generated within the specified time interval, with the exception of repetitions, variations, and in the letter task, proper names (Spreen & Strauss, 1998). Test-retest reliability is reported to be high over time periods ranging from 19 days (r = .88; desRosiers & Kavanagh, 1987) to one year (r = .70; Snow, Tierney, Zorzitto, Fisher, & Reid, 1988). In addition, a metacognitive task was included. Prior to the administration of each trial, participants were asked to predict the number of words they expected to generate on that trial. Similarly, participants were asked to postdict the number of words they generated upon completion of each trial. The number of words predicted/postdicted was recorded. Accuracy was established by (a) correlating prediction/postdiction scores with actual performance, and (b) dividing the prediction/postdiction score by the performance score for each trial, thereby establishing a ratio where perfect accuracy would result in an accuracy score of 1.0, with accuracy scores of greater or less than 1.0 indications of over or underestimates (McGlynn & Kaszniak, 1991).

California Verbal Learning Test. The California Verbal Learning Test (CVLT: Delis, Kramer, Kaplan, & Ober, 1987) is composed of 16 concrete nouns that can be grouped into four taxonomic categories presented in a fixed random order. Three memory tasks were used: (a) immediate recall, (b) 20-minute delayed recall, and (c) recognition memory. Two consecutive trials of immediate recall of the same word list (list A) were presented, consisting of (a) task instructions, (b) oral administration of the word list, (c) prediction, (d) list recall, and (e) postdiction. For Trial 1, participants were given the standard test instructions and the word-list was presented. Participants were then asked "Before you tell me the items I want you to tell me how many of the 16 items you think you will remember." This procedure was repeated for Trial 2. Participants were not told in advance that postdiction of performance would be measured. Following recall at each trial they were asked, " How many of the 16 words did you recall correctly?" Word lists were administered at a rate of one word per second, with self-paced recall. The procedure for the 20-minute delayed free-recall task differed only in that the word-list was not presented by the examiner. On completion of the 20-minute delayed free-recall task a recognition task was presented. Sixteen words from the original list were interspersed with an equal number of foils. Participants were asked to identify words from the original word-list. Following administration of the instructions, participants were asked to predict how many of the 16 words from the original word-list they would be able to recognize. Similarly, on completion of the recognition task participants were asked to postdict the number of correctly identified words. The word-list was then presented in a scrambled order and participants asked to arrange the words in the same order as the original

presentation, providing a measure of temporal recency. Temporal recency was scored as the number of words listed in the correct order of presentation.

Measures generated by the CVLT include (a) the total number of words recalled in each trial of immediate and delayed free recall, (b) the number of words recalled in the recognition trial, (c) semantic and serial clustering ratios, (d) the total number of perseverations, and (e) the total number of intrusions. In addition, each trial produced both a prediction and a postdiction value. Accuracy was established by (a) correlating prediction/postdiction scores with actual performance, and (b) dividing the prediction/postdiction value by the performance score for each trial, thereby establishing a ratio where perfect accuracy would result in an accuracy score of 1.0, with accuracy scores of greater or less than 1.0 indications of over or underestimates (McGlynn & Kaszniak, 1991).

Checkerboard task. This task was designed for this study to measure motor control and spatial ability. Equipment consisted of a standard checkerboard, marked in red and black squares, with accompanying markers. Participants were asked to place as many markers as possible within 30 seconds, on sequential squares, beginning at the far end of the board using their preferred hand. Participants who were right-handed were asked to start checker placement on the right-hand side of the board and participants who were left-handed were asked to start checker placement on the left-hand side of the board. Three trials were performed. On the first trial, participants were given instructions and a demonstration, then asked to practice the task by placing three checkers on the board. With the exception of omitting this phase on Trials 2 and 3, the trials were invariant,

consisting of (a) prediction of the number of markers correctly placed, (b) task completion, and (c) postdiction. The number of markers correctly placed were scored. The prediction and postdiction values were recorded. An accuracy score was calculated for each trial.

Handwriting task. The handwriting task provided a measure of fine motor dexterity (Dixon, Kurzman, & Friesen, 1993). Participants were asked to write the letter *h* as often as possible within 20 seconds, using a backward series of movements beginning at the lower right side of the letter. An answer sheet containing 121 cells, each containing a dot to specify the starting point for each letter, was provided. The number of legible letters generated within the specified time frame were scored. The handwriting task was conducted over three trials consisting of (a) task instructions and practice, (b) prediction, (c) task completion, and (d) postdiction. Participants were shown the answer sheet and given a demonstration of the task on the first trial. They were then asked "How many letters do you think you will be able to write within 20 seconds?" Postdiction was carried out following task completion. The procedure was invariant across three trials, with the exception of the exclusion of the demonstration on Trials 2 and 3. Prediction and postdiction estimates were recorded and accuracy scores were calculated for each trial.

California Card Sorting Test. The California Card Sorting Test (CCST: Delis, Squire, Bihrle, & Massman, 1992) was developed to assess several components of problem-solving ability related to executive function. The ability to initiate activity, formulate goals, plan strategies, and regulate behaviour are measured using three conditions. Condition one requires participants to sort six cards generating and identifying

up to eight different rules. In addition to the standardized instructions, participants were asked to predict the number of different ways they would be able to sort the cards. To be scored as correct, a rule must be equally applicable to the two groups (i.e., this pile has land animals and this pile has water animals). Rules that apply only to one group, with the absence of the identified element in the other group were scored as incorrect (i.e., this pile has the letter "e" and this pile does not). A three-minute time limit was imposed for each sort and a summary statement was prominently displayed with the instructions and identifying each correct sort as a reminder. Following removal of the reminders participants were asked to recall the number of sorts they accomplished. In condition two, participants were asked to identify each of the eight sorts performed by the examiner (Delis et al., 1992). The test was abbreviated to include only the first of three possible stimulus sets. Conditions were combined to produce three scores, (a) the total number of correct sorts and verbal responses, (b) percentage of correct sorts, and the (c) percentage of sorts repeated (Bondi et al., 1993). Prediction and postdiction values were recorded. Accuracy scores were calculated for each trial.

Prediction and postdiction performance. Prediction and postdiction scores and accuracy scores were produced for the following measures: (a) verbal fluency (4 trials), (b) CCST (condition one), (c) word list recall (4 trials), (d) checkerboard task (3 trials), and (e) handwriting task (3 trials). At the beginning of each task, participants were given a brief description of the task and asked to provide an estimate of their ability to complete task components. This procedure was repeated on subsequent trials with the omission of the task description, establishing a prediction score for each trial. On completion of each

trial, participants were asked to estimate their performance, generating a postdiction score. Accuracy scores were generated for each trial, following the method used by McGlynn and Kaszniak (1991) and described earlier in this paper.

General memory self-efficacy. General memory self-efficacy was measured with the Capacity subscale of the Metamemory in Adulthood Questionnaire (MIA; Dixon & Hultsch, 1983; Dixon, Hultsch, & Hertzog, 1988) and an item rating general memory from the Memory Functioning Questionnaire (MFQ; Gilewski & Zelinski, 1986). Participants were asked to report their beliefs regarding their memory abilities on daily tasks. The 17 questions on the MIA were rated on a 5-point scale ranging from (a) agree strongly to (e) disagree strongly. The question from the MFQ was rated on a 7-point scale anchored at (1) major problems and (7) no problems. Items were coded in a manner whereby higher scores would represent a perception of greater difficulty. Examples are shown in Table 2. Hultsch, Hertzog, Dixon, and Davidson (1988) report that the MIA Capacity scale has high internal consistency ($\propto = .84$). The MFQ Frequency of Forgetting scale, containing general memory rating has good convergent validity with the MIA Capacity Scale, with the two scales forming a higher-order factor identified as Memory Self-efficacy (MSE; Hertzog Hultsch, & Dixon, 1989).

Table 2

Metacognitive Questionnaire Examples

Questionnaire	Item	Example
	Memory Self-efficacy	
MIA Capacity subscale	17	I am good at remembering important dates.
MFQ Frequency of forgetting subscale	1	How would you rate your memory in terms of the kinds of problems you have.
	Movement Self-efficacy	
Movement capability	18	I can rise from a chair without difficulty.

Note. Items scored with higher scores representing a greater perception of difficulty.

General psychomotor self-efficacy. A short rating scale was developed for this study to assess participants' concept of their psychomotor capabilities. Eighteen questions asked participants to rate their ability to carry out common daily motor tasks on a 5-point scale ranging from (a) agree strongly to (e) disagree strongly. An example of the questions is presented in Table 2, with the full questionnaire provided in Appendix A.

Procedure

Participants were tested individually, with all measures presented within one testing session. The entire session required approximately two hours. Tasks were presented in the following groups. The MMSE was administered first, followed by the

questionnaire battery consisting of the demographic/health questionnaire, and the GDS. These tasks were completed at a self-paced rate, followed by the experimental tasks. The order of the experimental tasks were (a) verbal fluency, (b) immediate recall trials of the CVLT, (c) checkerboard trials, (d) handwriting trials, (e) CVLT 20-minute delayed recall and recognition task, (f) recency discrimination, and (g) CCST. Questionnaires assessing general memory and motor self-efficacy were the last measures presented.

Chapter IV

Results

The objectives of the statistical analyses are fourfold. First, age-related changes in the executive functioning, memory and motor performance of neurologically intact (NI) young-old and old-old adults are examined. Second, the performance of these groups is compared with that of a group of participants with PD. Third, age and group-related differences in metacognition are evaluated in the two NI and the PD groups. Fourth, the relation between executive function and awareness of memory and motor performance is assessed.

Profile analysis, a multivariate approach to repeated measures analysis of variance, was used to analyse group differences on measures with multiple trials. This method of analysis has fewer assumptions than alternative repeated measures analysis of variance procedures, increasing the reliability of significance tests (Tabachnick & Fidell, 1989). Profile analysis generates three tests of the data: a test of parallelism to determine if the slope between adjacent dependent variables are the same for each group; a test of flatness to determine if the profiles combined across groups deviate from zero; and the univariate test of levels to examine the differences between group means across trials. In the following analyses three levels of a grouping factor were used: NI young-old, NI old-old, and PD.

Reliability Analysis

The initial set of analyses examined the reliability of the questionnaires assessing awareness of daily memory and motor functioning.

Metacognitive questionnaires. The internal consistency of the Capacity subscale of the MIA and the Frequency of Forgetting subscale of the MFQ was assessed as one scale using Cronbach's alpha. As these measures are believed to be measuring a similar construct and the Frequency of Forgetting subscale consists of only one item the construct validity of the scale was not expected to be compromised. The standardized Cronbach's alphas for each of the participant groups on the Metamemory and Metamovement questionnaires are reported in Table 3. Internal consistency of the Metamemory scale for the NI groups in this study was generally similar to the results obtained by Dixon et al., (1988) for the Capacity subscale. They reported internal consistency reliabilities ranging from .81 to .86 in samples of healthy participants between the ages of 18 and 84 years. However, in the current study the items on the Metamemory questionnaire behaved in a less cohesive manner for the PD group, resulting in a Cronbach's alpha = .69. The internal consistency measure of the Metamovement questionnaire was reliable across groups, as shown in Table 3.

Table 3

Reliability Questionnaire Analysis

	Questionnaire				
	Cronbach's Alpha		Correlations with Metamovement		
Group	Memory	Movement	MIA	Memory	MFQ
NI Young-old	.89	.86	.44	.43	.20
NI Old-old	.84	.78	.29	.29	.07
PD	.69	.83	.12	.15	.27
Combined NI	.87	83	.42	.43	.23

Note. Memory denotes the Metamemory questionnaire (MIA and MFQ) and Movement denotes the Metamovement questionnaire.

Construct validity. Pearson product moment correlational analyses were conducted independently for each group to examine the relation between the Metamemory and the Metamovement questionnaires. Contrary to the hypothesis that the two questionnaires would be highly correlated, the relation between them was generally in the small range, suggesting that a limited amount of the variance associated with the multidimensional construct of metacognition is shared between the two questionnaires. As shown in Table 3, the relation between the Metamovement questionnaire and the MFQ was weaker for the NI groups than the correlation with the MIA, although this pattern was reversed with the PD group.

Group Differences on Tests of Executive Function

Verbal fluency. The hypotheses that the performance of the three groups of participants would differ on the total number of words generated on the verbal fluency task, and that the number of words generated in the semantic condition (Trial 4) would be greater than the number generated in the phonemic condition (Trials 1 to 3) were tested with a profile analysis performed with the four trials of verbal fluency as the dependent variables. A 3 x 4 (Group x Trial) multivariate analysis of variance (MANOVA) was performed with repeated measures on the Trial factor, representing the number of target words generated in response to the sum of the phonemic stimuli and the semantic stimuli, repeated across trials. Using the Wilks' criterion, the profiles did not deviate significantly from parallelism, $F(6,114) = .41$, $p = .87$, indicating that the Group by Trial interaction was not significant. The levels test revealed significant differences among the groups when the scores were averaged across trials, $F(2,59) = 9.20$, $p < .001$, $\eta^2 = .24$. Specifically, the NI young-old group ($M = 61.00$, $SD = 13.73$) and the NI old-old group ($M = 57.55$, $SD = 13.63$) generated more target words over the four trials than did the PD group ($M = 43.25$, 14.85). When averaged over groups, the trials were found by Hotelling's criterion to deviate significantly from flatness, $F(3,57) = 32.22$, $p < .001$, $\eta^2 = .63$, with the greatest number of words generated on Trial 4 ($M = 16.82$, $SD = 4.70$) and the least number generated on Trial 2 ($M = 11.52$, $SD = 11.52$). Planned univariate contrasts of the phonemic (mean of Trials 1 to 3) and the semantic conditions (Trial 4) averaged across groups showed that participants generated more words in the semantic

condition than in the phonemic condition, $F(3,59) = 21.80$, $p < .001$, $\eta^2 = .53$. Group means for the four trials of verbal fluency are presented in Table 4.

Table 4

Mean Verbal Fluency Scores

		Trial			
Group	n	1(F)	2(A)	3(S)	4(Animals)
NI Young-Old	22	13.64	13.05	15.32	19.00
(SD)		(4.12)	(4.15)	(4.26)	(4.59)
NI Old-Old	20	13.20	12.75	14.65	16.95
(SD)		(4.32)	(4.88)	(4.21)	(3.25)
Parkinson's	20	9.75	8.60	10.60	14.30
(SD)		(3.96)	(4.78)	(4.35)	(5.00)
Combined NI	42	13.43	12.91	15.00	18.02
(SD)		(4.17)	(4.46)	(4.20)	(4.10)

As the phonemic and semantic tasks of verbal fluency may require conceptually different skills a 3 x 3 (Group x Trial) MANOVA, with repeated measures on the trial factor of the phonemic condition (F,A,S), was conducted. Using a Wilks' criterion the test of parallelism was not significant, $F(4,116) = .23$, $p = .92$. As expected, the number of words generated in the phonemic condition was significantly related to group membership, $F(2,59) = 7.87$, $p = .001$, $\eta^2 = .21$, with a greater number of words generated by the NI young-old ($M = 42.00$, $SD = 10.32$) and the old-old groups ($M = 40.60$, $SD = 12.12$) relative to the PD group ($M = 28.95$, $SD = 12.23$). The profiles were found to deviate from flatness, Hotelling's $F(2,58) = 12.61$, $p < .001$, $\eta^2 = .30$. Planned univariate

difference contrasts of the marginal means for the Trial factor summed across groups, shows that the number of words generated in Trial 2 (M = 11.52, SD = 5.00) was significantly less than the number generated in Trial 3 (M = 13.58, SD = 4.69), $F(3,59)$ = 7.24, $p < .001$, $\eta^2 = .27$. A Bonferroni correction established alpha at .025. The contrast between Trial 1 and Trial 2 was not significant, $F(3,59) = .87$, $p = .46$.

An ANOVA conducted to compare the performance of the three groups on the semantic condition of the verbal fluency also found group differences, $F(2,59) = 6.12$, $p = .004$. As suggested by the means in Table 4, the NI young-old group generated more animal names than the PD group, Tukey's $HSD = -4.70$, $p = .003$. However, the contrasts between the NI groups (Tukey's $HSD = -2.05$, $p = .29$) and the NI old-old and the PD group (Tukey's $HSD = -2.65$, $p = .14$) were not significant at the Bonferroni corrected alpha level of .017.

The profiles of the NI young-old and old-old participants were compared on the phonemic trials to further investigate the effects of levels and flatness. The results of a 2 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor, did not support the hypothesis that NI old-old participants would produce fewer words in the phonemic condition than NI young-old participants, $F(1,40) = .163$, $p = .69$. Profiles did not deviate significantly from parallelism using the Wilks' criterion, $F(2,39) = .07$, $p = .94$, indicating that the slope of the profiles was similar for both groups. However, tests of flatness again found that the number of words generated differed significantly across trials of the phonemic condition using the Hotelling's criterion, $F(2,39) = 9.44$, $p < .001$, $\eta^2 = .33$. Planned univariate difference contrasts of the within subjects effects, with a Bonferroni

correction establishing alpha at .025, indicated that performance on Trial 1(F) was not significantly different from that on Trial 2(A), $\underline{F}(2,40) = .32$, $\underline{p} = .73$. However, comparison of Trials 2(A) and 3(S) revealed a significant difference, $\underline{F}(2,40) = 6.76$, $\underline{p} = .003$, $\eta^2 = .25$, with participants in both groups generating more words beginning with *S* in Trial 3 than they did words beginning with *A* in Trial 2, as indicated in the examination of the means for the combined NI group in Table 4.

As the NI young-old and the NI old-old groups did not differ on the number of words generated in the phonemic condition, a similar set of analyses was conducted to compare the profiles of the participants with PD and all NI participants combined in one group. A 2 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor, found that the groups differed significantly on the number of words generated in the phonemic condition, $\underline{F}(1,60) = 15.80$, $\underline{p} < .001$, $\eta^2 = .21$. The number of words generated by the NI participants was significantly higher ($\underline{M} = 41.33$, $\underline{SD} = 11.10$) than the number generated by the participants with PD ($\underline{M} = 28.95$, $\underline{SD} = 12.23$). When averaged over groups, the profiles were found by Hotelling's criterion to deviate significantly from flatness, $\underline{F}(2,59) = 10.60$, $\underline{p} < .001$, $\eta^2 = .26$, indicating that the profile slopes deviated from zero over the course of the three trials. However, changes in the profile slopes were similar for both groups as the test for parallelism was not significant using Wilks' criterion, $\underline{F}(2,59) = .40$, $\underline{p} = .67$. Planned univariate difference contrasts of the marginal means for the Trial factor summed across groups, showed that while the number of words generated in Trial 1 was not significantly different from Trial 2, $\underline{F}(2,60) = 1.32$, $\underline{p} = .28$, participants produced more words in Trial 3 than they did in the previous trial, $\underline{F}(2,60) = 10.96$, $\underline{p} <$

.001, $\eta^2 = .27$ (Trial 3: M = 13.58, SD = 4.69; Trial 2: M = 11.52, SD = 4.96, respectively).

In summary, age-related changes in the ability to generate words starting with the target letters of *F, A,* and *S* and names of animals were not evident in this sample of neurologically intact older adults. However, the group of participants with PD failed to generate as many words in the phonemic condition as their NI counterparts, and they generated fewer animal names than the NI young-old group. All groups showed similar changes in the performance over the four trials, with the slope remaining flat between Trials 1(F) and 2(A), then increasing for Trials 3(S). As well, more words were generated in Trial 4 (semantic condition) than in the previous trials (phonemic condition).

California Card Sorting Test. The modified California Card Sorting Test (CCST) was expected to reveal differences in performance related to age and diagnosis of participants. This hypothesis was tested with a one-way ANOVA with group membership as the independent variable representing the NI young-old, NI old-old, and PD groups. The CCST score, determined by the number of correct sorts summed across conditions 1 and 2 was the dependent variable. Results indicated that the average number of sorts generated within each group was significantly different, $F(2,59) = 6.19$, $p = .004$, $\eta^2 = .17$. As suggested by an inspection of the means in Table 5, post-hoc pairwise comparisons of group scores, with a Bonferroni correction establishing alpha at .017, showed that the NI young-old group generated or identified more correct sorts than the NI old-old group, Tukey's HSD = -2.17, $p = .017$. While the group with PD scored significantly lower on

this sorting task than the NI young-old group, Tukey's HSD = -2.42, p = .007, their level of performance was similar to that of the old-old NI group, Tukey's HSD = -.25, p = .95.

Table 5

Mean California Card Sorting Test Scores

		Measure		
Group	n	Score	Percent Accurate	Perseveration
NI Young-Old	22	7.82	64.31	2.00
(SD)		(2.58)	(19.36)	(2.60)
NI Old-Old	20	5.65	55.50	2.15
(SD)		(2.85)	(22.82)	(2.25)
Parkinson's	20	5.40	54.79	2.30
(SD)		(1.85)	(18.35)	(2.34)

To test the hypothesis that the percentage of accurate responses would vary depending on group membership, a one-way ANOVA, with the three groups as the independent variable was conducted. This analysis failed to find a significant effect for group, F(2,59) = 1.46, p = .24. A one-way ANOVA, with the three groups as the independent variable and the total number of perseverative responses as the dependent variable, also failed to find a significant effect, F(2,59) = .08, p = .92. In summary, while the number of correct sorts generated was significantly related to age, with the NI young-old group generating and identifying more sorts than the NI old-old group, the relation to diagnosis was limited as the performance of the PD group was similar to that of the NI old-old group. Analysis did not support a significant effect for group membership for the

percentage of accurate responses or the number of perseverations, although the group means were in the expected direction.

California Verbal Learning Test executive function measures. Three CVLT measures were considered to reflect aspects of executive function, recall strategy (i.e., semantic and serial), recall errors (i.e., perseverations and intrusions), and temporal recency (i.e., reconstruction of the word list). In the following analyses variables sharing the same scale of measurement were analysed together resulting in two separate MANOVAs using group (NI young-old, NI old-old, and PD) as the independent variable. In the first analysis, groups were compared on the dependent variable of the recall strategy. In the second, the total number of perseverations and intrusions on recall were the dependent variables. In each case the MANOVA failed to show a significant effect using Wilks' criterion, $F(4,116) = .14$, $p = .97$ and $F(4,116) = .42$, $p = .79$, for recall strategy and recall errors respectively.

To investigate the hypotheses that the NI young-old participants would produce fewer errors in word-list order on the temporal recency measure than the NI old-old group and the PD group, and that the PD group would produce more errors than the NI groups a one-way ANOVA was conducted. Group membership, including the NI young-old, the NI old-old, and the PD groups, was the independent variable in this analysis, with the number of words correctly reordered to match the original word-list as the dependent variable. The analysis failed to show a significant difference between the groups $F(2,56) = .61$, $p = .55$. Means and standard deviations for the CVLT executive function measures are presented in Table 6.

Table 6

Mean California Verbal Learning Test Executive Function Scores

		Measure				
Group	n	Semantic	Serial	Perseverations	Intrusions	Recency[a]
Young-old	22	1.68	4.60	.81	1.76	2.25
(SD)		(.82)	(6.30)	(1.22)	(1.93)	(1.02)
Old-old	20	1.57	5.49	.50	1.35	2.21
(SD)		(.68)	(10.49)	(1.00)	(1.35)	(1.44)
PD	20	1.54	4.24	.63	1.26	1.82
(SD)		(.90)	(11.77)	(1.09)	(1.86)	(1.43)

Note. [a] n = 17 in the PD group for this measure.

Group Differences on Tasks of Memory

California Verbal Learning Test Memory Measures. The hypothesis that the three groups of participants would differ on memory performance was tested with a profile analysis with the four trials of the CVLT as the dependent variables. A 3 x 4 (Group x Trial) MANOVA was performed, with repeated measures on the Trial factor. The four levels of Trial represented the number of list-words recalled in the first three trials and the number of list-words correctly identified in the fourth trial. Using the Wilks' criterion, the profiles did not deviate significantly from parallelism, $F(6,114) = .87$, $p = .52$, indicating that profile slopes were similar for all groups. The levels test revealed significant differences among the groups when averaged across trials, $F(2,59) = 7.84$, $p = .001$, $\eta^2 = .21$ (NI young-old $M = 35.62$, $SD = 7.19$; NI old-old $M = 34.60$, $SD = 8.10$; PD $M = 27.36$, $SD = 6.45$). When averaged over groups, the trials were found by Hotelling's

criterion to deviate significantly from flatness, $F(3,57) = 247.17$, $p < .001$, $\eta^2 = .93$. A planned univariate contrast was conducted to determine whether this sample showed the expected differences with the average number of words recalled on each trial (Trials 1 to 3) less than the number of words recognized (Trial 4). Analysis confirmed a large effect size for memory condition represented in this contrast, $\eta^2 = .91$. The participants recognized more list-words than they were able to generate in the free recall condition, $F(3,59) = 205.68$, $p < .001$ (Trial 1: $M = 5.23$, $SD = 2.02$; Trial 2: $M = 7.67$, $SD = 2.57$; Trial 3: $M = 6.71$, $SD = 2.83$; Trial 4: $M = 13.02$, $SD = 2.05$). Means and standard deviations are presented for each group of participants on the individual trials in Table 7.

Table 7

Mean California Verbal Learning Test Memory Scores

		Trial			
Group	n	1	2	3	4
NI Young-Old	22	6.00	8.57	7.71	13.33
(SD)		(1.63)	(2.22)	(2.75)	(1.86)
NI Old-Old	20	5.45	8.25	7.20	13.70
(SD)		(2.28)	(2.71)	(2.65)	(2.16)
Parkinson's	20	4.15	6.11	5.11	12.00
(SD)		(1.73)	(2.13)	(2.51)	(1.84)
Combined NI	42	5.74	8.42	7.47	13.51
(SD)		(1.96)	(2.44)	(2.68)	(1.99)

Note. Trials 1 to 3 are measures of free recall, while Trial 4 is a measure of recognition.

As the free recall and recognition trials of the CVLT may be tapping different aspects of memory function a 3 x 3 (Group x Trial) MANOVA, with repeated measures

on the trial factor, was conducted. Free recall trials (1 to 3) of the CVLT were the dependent variables, with the three groups as the independent variable. Using Wilks' criterion the profiles did not deviate from parallelism, $F(4,116) = .709$, $p = .587$, indicating that the Group by Trial interaction was not significant. In contrast, the levels effect found significant differences in recall between the groups, $F(2,59) = 7.30$, $p = .001$, $\eta^2 = .20$. Recall performance of the NI groups (young-old $M = 22.29$, $SD = 5.95$; old-old $M = 20.90$, $SD = 6.85$) was higher than that of the PD group ($M = 15.36$, $SD = 5.61$). Profiles were also found to deviate significantly from flatness using the Hotelling's criterion, $F(2,58) = 60.14$, $p < .001$, indicating a significant effect for Trial. Planned univariate contrasts of the marginal means for the Trial factor, with a Bonferroni correction establishing alpha at .025, found that recall means increased on the second immediate recall trial (Trial 2 $M = 7.67$, $SD = 2.57$) relative to the first (Trial 1 $M = 5.23$, $SD = 2.02$), and as expected, the recall on the delayed trial (Trial 3 $M = 6.71$, $SD = 2.83$) was lower than on the second immediate recall trial.

An ANOVA was conducted to compare the performance of the three groups on the recognition trial of the CVLT (Trial 4). While the results indicate that the number of words recognized was dependent on group membership, $F(2,59) = 4.23$, $p = .019$, $\eta^2 = .13$, post hoc analysis show that this finding is primarily due to difference in the performance of the NI young-old and the PD groups, Tukey's $HSD = 1.70$, $p = .02$. As seen in Table 7, the recognition performance of the two NI groups was similar, Tukey's $HSD = .37$, $p = .82$, with a somewhat greater difference in the performances of the NI old-

old and the PD groups, Tukey's HSD = -1.33, $p = .08$. With the Bonferroni correction establishing alpha at .017 specific group contrasts failed to reach significance.

The profiles of the young-old and the old-old NI participants were compared on the free recall trials (Trials 1 to 3) to further investigate the effects of levels and flatness. The results of a 2 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor, did not support the hypothesis that NI old-old participants would recall fewer words than NI young-old participants, $F(1,40) = .49$, $p = .49$. Profiles did not deviate significantly from parallelism using the Wilks' criterion, $F(2,39) = .12$, $p = .89$. However, tests of flatness using the Hotelling's criterion found that the slope between Trials deviated significantly from zero, $F(2,39) = 45.96$, $p < .001$, $\eta^2 = .70$. Planned univariate difference contrasts of within subjects effects, with a Bonferroni correction establishing alpha at .025, found the number of words recalled on Trial 1 was significantly less than the number recalled on Trial 2, $F(2,40) = 46.38$, $p < .001$, $\eta^2 = .70$. As shown in Table 7, the combined NI group of participants recalled more words on the second free recall trial of the CVLT than on the first trial. Further, the number of words recalled on the second free recall learning trial was significantly greater than the number recalled on the third recall trial following a delay, $F(2,40) = 6.50$, $p = .004$, $\eta^2 = .25$, confirming that this sample experienced the expected memory decay over the 20-minute delay interval.

A similar set of analyses were conducted to compare the profiles of the participants with PD with the combined group of NI participants on the dependent variables of the CVLT free recall Trials 1 to 3. A 2 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor, showed that the test of parallelism was not

significant using the Wilks' criterion, $F(2,59) = 1.34$, $p = .27$. However, the groups differed significantly on the number of words recalled when averaged across trials, $F(1,30) = 14.17$, $p < .001$, $\eta^2 = .19$, with the NI group recalling more list words ($M = 21.63$, $SD = 6.35$) than the group with PD ($M = 15.36$, $SD = 5.61$). As well, when averaged over groups the profiles deviated significantly from flatness using the Hotelling's criterion, $F(2,59) = 48.35$, $p < .001$, $\eta^2 = .62$. To further investigate this effect, planned univariate difference contrasts of the marginal means for the within subjects Trial factor showed that participants recalled fewer words on Trial 1 than on Trial 2, $F(2,60) = 62.93$, $p < .001$, $\eta^2 = .68$. As expected, participants also recalled fewer words in the delayed condition (Trial 3) than in the second learning condition (Trial 2), $F(2,60) = 9.33$, $p < .001$, $\eta^2 = .24$.

To evaluate the group differences in immediate recall over the first two trials on the CVLT, a 3 x 2 (Group x Trial) ANOVA was conducted, with repeated measures on the Trial factor. The groups showed the expected differences across the two trials, $F(2,59) = 7.02$, $p = .002$, $\eta^2 = .19$. Consistent with the previous analyses the NI young-old group recalled more words ($M = 14.57$, $SD = 3.54$) than the NI old-old group ($M = 13.70$, $SD = 4.60$), and both NI groups recalled more words than the PD group ($M = 10.26$, $SD = 3.52$). The Group by Trial interaction was not significant, $F(2,59) = 1.26$, $p = .29$, however, scores varied significantly between the two trials, $F(1,59) = 121.15$, $p < .001$, $\eta^2 = .33$. All groups recalled more words on the second trial ($M = 7.67$, $SD = 2.57$) than on the first ($M = 5.23$, $SD = 2.02$).

A 3 x 3 (Group x Trial) MANOVA was conducted, with memory trial as the dependent variable, to compare group differences on immediate free recall (Trial 1 and 2)

and the recognition task (Trial 4). The NI young-old, NI old-old, and the PD groups were the independent variable. Using Wilks' criterion, the groups did not deviate from parallelism, $F(4,116) = 1.16$, $p = .33$, indicating that the profile pattern was similar for all groups. Nevertheless, there was a significant difference in group performance across these three trials of the CVLT, evident in the significant levels effect, $F(2,59) = 7.76$, $p = .001$, $\eta^2 = .21$. Both NI groups had a higher level of performance (young-old: $M = 27.91$, $SD = 4.70$; old-old: $M = 27.40$, $SD = 5.78$), than the PD group ($M = 22.25$, $SD = 4.70$). When summed across groups the profiles deviated significantly from flatness using Hotelling's criterion, $F(2,58) = 363.80$, $p < .001$, $\eta^2 = .93$. Planned univariate difference contrasts, with Bonferroni corrected alpha established at .025, indicated that group performance was significantly lower on Trial 1 ($M = 5.23$, $SD = 2.02$) than on Trial 2 ($M = 7.67$, $SD = 2.57$), indicating that participants' memory performance improved with repeated trials, $F(3,59) = 41.44$, $p < .001$, $\eta^2 = .69$. As expected, performance on Trial 4 ($M = 13.02$, $SD = 2.05$) was significantly higher than on Trial 2, $F(3,59) = 118.57$, $p < .001$, $\eta^2 = .86$. These results indicate that the following a delay, the participants were able to remember a greater number of words with the cognitive support of a recognition format than they were able to remember immediately following two repetitions of list presentation in a free recall condition.

In summary, age-related differences on memory tasks of word-list recall and recognition were not evident in this sample. However, diagnosis had a significant effect on free-recall, as the NI participants showed a significantly higher level of performance on these memory tasks than the group of participants with PD. As expected, the number of

words recalled following the second presentation of the word-list was greater than the number recalled on the first, for all groups, while the number recalled following a 20-minute delay dropped significantly relative to Trial 2. Similarly, all participants scored higher on the recognition task than on tasks demanding free recall of list-words.

Group Differences on Motor Tasks

Checkerboard Task. The performance of the NI and PD participants on a task requiring the rapid placement of checkers on a board was compared using a profile analysis across the three trials, with group membership as the independent variable. A 3 x 3 (Group x Trial) MANOVA was conducted with repeated measures on the Trial factor. Using a Wilks' criterion the groups did not deviate from parallelism, $F(4,116) = .74$, $p = .57$. In contrast, the test of levels was significant, $F(2,59) = 22.27$, $p < .001$, $\eta^2 = .43$, indicating a significant group effect. Participants with PD placed fewer checkers over the three trials ($M = 45.60$, $SD = 9.27$) than the NI young-old participants ($M = 63.23$, $SD = 8.24$), and the NI old-old participants ($M = 54.95$, $SD = 8.12$). The groups also showed a significant deviation from flatness using the Hotelling's criterion, $F(2,58) = 23.36$, $p < .001$, $\eta^2 = .45$, indicating a significant Trial effect. Planned univariate difference contrasts of the C matrix showed that the number of checkers placed in Trial 2 was a significant increase over the number placed in Trial 1, $F(3, 59) = 10.29$, $p < .001$, $\eta^2 = .34$ (Trial 2: $M = 18.57$, $SD = 3.96$; Trial 1: $M = 17.24$, $SD = 3.65$, respectively). However, the number of checkers placed in Trial 3 failed to showed a significant increase over Trial 2, $F(3,59) = 2.61$, $p = .06$, although a slight increase in mean scores was apparent ($M = 19.07$, $SD = 3.98$). Trial means and standard deviations for each group are presented in Table 8.

Table 8

Mean Checkerboard Scores

		Trial		
Group	n	1	2	3
NI Young-Old	22	19.86	21.36	22.00
(SD)		(2.77)	(3.03)	(3.51)
NI Old-Old	20	17.15	18.80	19.00
(SD)		(2.87)	(2.93)	(3.06)
Parkinson's	20	14.45	15.25	15.90
(SD)		(3.14)	(3.29)	(3.39)
Combined NI	42	18.57	20.14	20.57
(SD)		(3.10)	(3.22)	(3.32)

A comparison of the profiles of the young-old NI participants and their old-old counterparts on the three trials of the checkerboard task was conducted to further investigate the effects of levels and flatness. The results of a 2 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor, showed a significant effect for levels, $F(1,40) = 10.72$, $p = .002$, $\eta^2 = .21$. NI young-old participants placed more checkers on the board during the test time ($M = 63.23$, $SD = 8.24$) than the old-old participants ($M = 54.95$, $SD = 8.12$). The test for flatness using the Hotelling's criterion showed that the profiles differed significantly across trials, $F(2,39) = 18.06$, $p < .001$, $\eta^2 = .48$. The profiles did not deviate significantly from parallelism using the Wilks' criterion, $F(2,39) = .47$, $p = .63$. Planned univariate contrasts of the Trial effects, with a Bonferroni correction establishing alpha at .025, showed that the number of checkers placed on the

second trial (M = 20.14, SD = 3.22) was greater than the number placed on the first trial (M = 18.57, SD = 3.10), $F(2,40) = 15.06$, $p < .001$, $\eta^2 = .43$. However, the number of checkers placed on the board within the test time in Trial 3 (M = 20.57, SD = 3.32) was not significantly greater than the number placed during Trial 2, $F(2,40) = 2.30$, $p = .11$.

As the performance of the NI groups was found to be related to age, as shown in the previous set of analyses, separate analyses were conducted to compare each NI group independently with the PD group. A 2 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor and the NI young-old and PD groups as the independent variable, was conducted. As with the previous analyses the effect of parallelism was not significant, $F(2,39) = .87$, $p = .43$. The results showed a significant effect for levels, $F(1,40) = 42.57$, $p < .001$, $\eta^2 = .52$, with the NI young-old group placing more checkers (M = 63.23, SD = 8.24) than the group with PD (M = 45.60, SD = 9.27). Using the Hotelling's criterion the profiles were also found to deviate significantly from flatness, $F(2,39) = 20.02$, $p < .001$, $\eta^2 = .51$. Planned univariate contrasts of the Trials effect, with a Bonferroni correction establishing alpha at .025, indicated that more checkers were placed on Trial 2 (M = 18.45, SD = 4.39) than on Trial 1 (M = 17.29, SD = 4.00), $F(2,40) = 8.61$, $p = .001$, $\eta^2 = .30$. However, the number of checkers placed on Trial 3 (M = 19.10, SD = 4.38) did not differ significantly from the number placed on Trial 2, $F(2,40) = 3.56$, $p = .038$.

Comparing the scores of the NI old-old group with those of the PD group on the checkerboard task revealed a similar pattern of results. A 2 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor, showed a significant levels effect,

$F(1,38) = 11.51$, $p = .002$, $\eta^2 = .23$. As expected, the NI old-old group placed more checkers on the board during the test time ($M = 54.95$, $SD = 8.12$) than the participants with PD ($M = 45.60$, $SD = 9.27$). The profiles were not found to deviate significantly from parallelism, $F(2,37)$ .97, $p = .39$. However, there was a significant Trial effect, as shown by the test of flatness, Hotelling's $F(2,37) = 11.04$, $p < .001$, $\eta^2 = .37$. Planned univariate contrasts to further investigate the change in performance across trials, with a Bonferroni correction establishing alpha at .025, showed that the number of checkers placed in the second trial ($M = 17.03$, $SD = 3.56$) was greater than the number placed in the first trial ($M = 15.80$, $SD = 3.27$), $F(2,38) = 7.80$, $p = .001$, $\eta^2 = .29$. As expected, Trial 3 ($M = 17.45$, $SD = 3.55$) did not differ significantly from Trial 2, $F(2,38) = 1.92$, $p = .16$.

In summary, performance on the checkerboard task was found to be significantly related to age and diagnosis. The NI young-old participants were able to place more checkers on the board during the test time than the NI old-old participants, and both NI groups placed more checkers than the PD group. All groups placed a greater number of checkers on the board on their second trial compared to the first, then performance remained relatively stable for Trial 3.

Handwriting Task. The hypothesis that the three groups would differ in the number of backward *h*s they were able to write within the test time was examined with a profile analysis including the three trials of the handwriting task as the dependent variable, with group membership as the independent variable. A 3 x 3 (Group x Trial) MANOVA, with repeated measures on Trial factor, showed that the profiles deviated significantly

from parallelism using a Wilks' criterion, $F(4,116) = 3.09$, $p = .018$, $\eta^2 = .18$, indicating a significant Group by Trial interaction. An inspection of the means in Table 9 shows a greater increase in performance between Trial 1 and 2 for the NI groups, then a much smaller improvement on Trial 3. In contrast, the performance of the PD group shows little increase between Trials 1 and 2, while showing a greater increase on Trial 3. The levels test revealed a significant effect for group, $F(2,59) = 16.35$, $p < .001$, $\eta^2 = .36$, with the NI young-old participants generating more letters over the three trails ($M = 53.00$, $SD = 10.38$) than the NI old-old participants ($M = 45.40$, $SD = 8.39$), and both NI groups generating more letters than the PD participants ($M = 35.70$, $SD = 10.43$). The profiles also deviated significantly from flatness using the Hotelling's criterion, $F(2,58) = 32.64$, $p < .001$, $\eta^2 = .53$. As inspection of Table 9 indicates, all groups showed a general increase from Trial 1 to Trial 3. Further analyses were conducted to examine the interaction found between the Group and Trial factors and the Group effects.

Table 9

Mean Handwriting Scores

		Trial		
Group	n	1	2	3
NI Young-Old	22	15.86	18.32	18.82
(SD)		(3.51)	(3.71)	(3.71)
NI Old-Old	20	13.60	15.35	16.45
(SD)		(3.14)	(3.10)	(2.72)
Parkinson's	20	11.30	11.75	12.65
(SD)		(3.42)	(3.78)	(3.86)

Pairwise analyses of the three groups were conducted to follow-up the significant effects of the omnibus analysis for the handwriting task. The first set of analyses compared the profiles of the NI young-old and old-old participants to further examine the effect of age and changes in performance across repeated trials. A 2 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor, was conducted with Trials 1 to 3 of the handwriting task as the dependent variables. The profiles were not found to deviate significantly from parallelism using the Wilks' criterion, $\underline{F}(2,39) = 1.09$, $\underline{p} = .35$, indicating that the pattern of performance for these two groups was similar across trials. The test of the levels effect showed a significant Group effect, $\underline{F}(1,40) = 6.72$, $\underline{p} = .013$, $\eta^2 = .14$, with the NI young-old group producing more *h*s across the trials than the NI old-old group. The profiles also showed a significant deviation from flatness using a Hotelling's criterion, $\underline{F}(2,39) = 41.82$, $\underline{p} < .001$, $\eta^2 = .68$. Planned univariate contrasts of the Trials factor, with a Bonferroni correction establishing alpha at .025, found scores on Trials 1 ($\underline{M} = 14.77$, $\underline{SD} = 3.49$) significantly lower than on Trial 2 ($\underline{M} = 16.91$, $\underline{SD} = 3.71$), $\underline{F}(2,40) = 30.96$, $\underline{p} < .001$, $\eta^2 = .61$. Trials 2 and 3 ($\underline{M} = 17.69$, $\underline{SD} = 3.45$) were also found to be significantly different in the number of *h*s produced, $\underline{F}(2,40) = 4.59$, $\underline{p} = .016$, $\eta^2 = .19$. An inspection of the means in Table 9 reveals a significant improvement in performance across trials, with NI young-old and old-old participants producing more *h*s with each subsequent trial.

As the performances of the NI groups were significantly different across trials a similar set of profile analyses compared each NI group individually with the group of participants with PD using a 2 x 3 (Group x Trial) MANOVA, with repeated measures on

the Trial factor. Thus, in the second set of follow-up analyses the NI young-old group and the PD group represented the independent variable in the MANOVA. As expected, analysis revealed a significant levels effect, $F(1,40) = 28.95$, $p < .001$, $\eta^2 = .42$, with the NI young-old group producing more writing samples ($M = 53.00$, $SD = 10.38$) than the PD group ($M = 35.70$, $SD = 10.43$) across the three trials. The test of flatness also showed a significant effect using the Wilks' criterion, $F(2,39) = 16.32$, $p < .001$, $\eta^2 = .46$. The profiles of the NI young-old and the PD groups were also found to deviate significantly from parallelism using the Hotelling's criterion, $F(2,39) = 5.63$, $p = .007$, $\eta^2 = .22$.

To examine the significant Group by Trial interaction profile analyses were conducted using one-way ANOVAs, with repeated measures on the Trial factor and handwriting scores as the dependent variable, for the NI young-old and the PD groups independently. Bonferroni adjusted alpha was established at .005. As expected, each group showed a unique pattern of change. The test for flatness was significant using the Hotelling's criterion for the NI young-old $F(2,20) = 24.74$, $p < .001$, $\eta^2 = 71$. However, handwriting scores for the PD group did not differ across trials with the Bonferroni adjustments, Hotelling's $F(2,18) = 3.77$, $p = .043$. Planned univariate contrasts for the Trial effect for the NI young-old found Trial 1 and 2 to be significantly different, $F(1,21) = 43.87$, $p < .001$, $\eta^2 = .68$. However, the number of *h*s produced on the third trial did not differ significantly from the second trial, $F(1,21) = 1.53$, $p = .23$. Means and standard deviations for each group are presented in Table 9.

In the third set of follow-up analyses the results of the 2 x 3 (Group x Trial) MANOVA comparing the profiles of the NI old-old and the PD groups showed that the profiles did not deviate significantly from parallelism using the Wilks' criterion, $F(2,37) = 2.34$, $p = .11$. However, the test for levels showed a significant Group effect, $F(1,38) = 10.50$, $p = .002$, $\eta^2 = .22$, with the NI old-old group producing more letters ($M = 45.40$, $SD = 8.39$) than the PD group ($M = 35.70$, $SD = 10.43$). The profiles also showed a significant deviation from flatness using the Hotelling's criterion, $F(2,37) = 15.78$, $p < .001$, $\eta^2 = .46$, indicating significant change across trials when collapsed across groups. Planned univariate contrasts of the within subjects Trial effect, with a Bonferroni correction establishing alpha at .025, showed that a greater number of letters were produced in each subsequent trial: Trial 1 ($M = 12.45$, $SD = 3.44$) and 2 ($M = 13.55$, $SD = 3.87$), $F(2,38) = 8.46$, $p = .001$, $\eta^2 = .31$; and Trial 2 and 3 ($M = 14.55$, $SD = 3.82$), $F(2,38) = 8.03$, $p = .001$, $\eta^2 = .12$.

Overall, the performance of the three groups was very different on the handwriting task. The NI young-old participants generated more backward *h*s on each trial than the NI old-old participants, and both groups produced more letters than the participants with PD. While the mean performance generally increased with each trial for all groups, the performance of the NI young-old group rose sharply on the second trial, relative to the first, and then showed little change on the third trial. The performance pattern of the NI old-old group was similar. However, the performance gains across trials for the PD group were significantly smaller than those of the NI young-old group, resulting in a much flatter profile and accounting for the interaction between these groups across trials.

Group Differences on Tasks of Metacognition

Group differences in the pattern of performance was expected to remain consistent across measures of metacognition. In this section, the actual values of predictions and postdictions were analysed, followed by an examination of the relation between these two measures. Next, prediction and postdiction accuracy scores were analysed and the relation between these measures was assessed. Finally, analyses of the metacognitive questionnaires and the relation of these responses to other measures of metacognition were conducted. Overall, it was expected that NI young-old participants would show a greater awareness of executive, memory, and motor function than the NI old-old participants. Further, the participants with PD were expected to be less aware of their performance than the NI groups.

Performance Predictions. Profile analysis was conducted using a 3 x 4 (Group x Trial) MANOVA, with repeated measures on the Trial factor, to assess differences between the NI young-old, NI old-old, and the PD groups in performance predictions in verbal fluency. There were no significant group differences in prediction, $F(2,59) = 1.77$, $p = .18$, and predictions remained relatively constant across Trials as reflected in the test for flatness using Hotelling's criterion, $F(3,57) = 2.39$, $p = .08$. Profiles were not found to deviate significantly from parallelism, Wilks' $F(6,114) = 1.51$, $p = .18$. As seen in the means and standard deviations for verbal fluency predictions for each group presented in Table 10, there is little difference in performance predictions between the three groups or across the trials.

Table 10

Mean Performance Predictions Across Trials for Verbal Fluency

Group	n	Trial 1 (SD)	Trial 2 (SD)	Trial 3 (SD)	Trial 4 (SD)
NI Young-old	22	18.73 (14.00)	16.82 (11.75)	16.32 (11.53)	15.32 (7.74)
NI Old-old	20	13.05 (4.75)	12.85 (6.45)	13.70 (5.81)	14.80 (5.47)
PD	20	14.25 (10.44)	11.15 (5.84)	10.45 (5.29)	12.25 (5.95)

Before the prediction scores from Trial 1 of the CCST were submitted to an ANOVA two outlying scores from the NI old-old group were replaced with group means. Results of the analysis revealed reliable differences in performance predictions of the three groups $F(2,59) = 4.70$, $p = .013$, $\eta^2 = .14$. Post hoc Tukey's pairwise comparisons, with a Bonferroni correction establishing alpha at .017, found that the NI young-old group ($M = 5.05$, $SD = 1.86$) predicted a higher number of correct sorts than the NI old-old participants ($M = 3.50$, $SD = 1.14$), $HSD = -1.55$, $p = .009$. The predictions of the PD group ($M = 4.25$, $SD = 1.77$) were similar to those of the NI groups (NI young-old and PD: $HSD = -.80$, $p = .26$; NI old-old and PD: $HSD = .75$, $p = .32$).

A 3 x 4 (Group x Trial) MANOVA, with repeated measures on the Trial factor, found significant group differences in prediction of CVLT performance, $F(2,59) = 3.30$, $p = .04$, $\eta^2 = .10$, with the predictions of the NI young-old ($M = 32.43$, $SD = 7.69$) only slightly higher than those of the NI old-old group ($M = 30.10$, $SD = 7.62$). The predictions of both NI groups were higher than the PD group ($M = 26.84$, $SD = 5.57$). The groups did not deviate from parallelism, Wilks' $F(4,114) = .72$, $p = .64$. The test for flatness showed a significant change in prediction across trials, Hotelling's $F(3,57) =$

27.12, $p < .001$, $\eta^2 = .59$. The greatest change in performance prediction on the CVLT occurred between Trials 3 ($M = 6.81$, $SD = 1.84$) and 4 ($M = 9.21$, $SD = 2.88$), as shown in the difference contrasts of marginal means for the Trial factor, $F(3,59) = 22.96$, $p < .001$, $\eta^2 = .54$. With a Bonferroni correction establishing alpha at .017, the contrast between Trial 1 ($M = 6.52$, $SD = 1.94$) and Trial 2 ($M = 7.33$, $SD = 2.30$) also showed significant change in prediction performance on the CVLT, $F(3,59) = 3.80$, $p = .015$, $\eta^2 = .16$. The difference in prediction scores between Trials 2 and 3 was not significant, $F(3,59) = 1.87$, $p = .15$. The changes in prediction between Trials 1 and 2 suggests an understanding of the efficacy of repeated trials when learning new information. Increases in prediction for the recognition trial is likely indicative of an understanding of the usefulness of this memory strategies for improving performance. Given this pattern of predictions it is somewhat surprising that most participants did not expect a significant decline in recall performance following an activity-filled delay, evident in the similar means for Trials 2 ($M = 7.33$, $SD = 2.30$) and 3 ($M = 6.81$, $SD = 1.84$). The means and standard deviations for each group across trials are presented in Table 11.

Table 11

Mean Performance Predictions Across Trials on the California Verbal Learning Test

Group	n	Trial 1 (SD)	Trial 2 (SD)	Trial 3 (SD)	Trial 4 (SD)
NI Young-old	22	7.10 (2.07)	7.86 (2.38)	7.24 (2.09)	10.24 (2.67)
NI Old-old	20	6.35 (1.69)	7.40 (2.44)	6.95 (1.64)	9.40 (3.30)
PD	20	6.05 (1.96)	6.68 (2.00)	6.21 (1.67)	7.90 (2.20)
Combined NI	42	6.74 (1.91)	7.64 (2.39)	7.10 (1.87)	10.61 (3.24)

Follow-up analyses were conducted using profile analysis to further investigate group differences in prediction of CVLT performance. A 2 x 4 (Group x Trial) MANOVA, with repeated measures on the Trial factor, failed to find group differences in CVLT prediction scores between the NI young-old and the old-old groups, $F(1,40) = .97$, $p = .331$. Profiles did not deviate from parallelism, Wilks' $F(3,38) = .30$, $p = .83$. As with the omnibus analysis, prediction scores of these groups changed across trials, Hotelling's $F(3,38) = 22.77$, $p < .001$, $\eta^2 = .64$. Planned univariate difference contrasts of the marginal means for the Trial factor, with a Bonferroni correction establishing alpha at .017, showed that the greatest change was apparent between Trials 3 ($M = 7.10$, $SD = 1.88$) and 4 ($M = 9.94$, $SD = 2.98$), $F(2,40) = 26.40$, $p < .001$, $\eta^2 = .57$, while a more modest change occurred between Trials 1 ($M = 6.74$, $SD = 1.91$) and 2 ($M = 7.64$, $SD = 2.39$), $F(2,40) = 5.41$, $p = .008$, $\eta^2 = .21$. Predictions showed little change between Trials 2 and 3, $F(2,40) = 1.84$, $p = .17$, despite the 20-minute intervening delay.

A similar set of analyses were conducted to assess differences in CVLT performance predictions between the combined NI and PD groups. The analyses showed

that the predictions varied by group, $F(1,60) = 5.45$, $p = .023$, although the effect size was small, $\eta^2 = .08$. The predictions of the NI group ($M = 31.32$, $SD = 7.66$) were higher than those of the PD group ($M = 26.84$, $SD = 5.57$). Profiles did not deviate from parallelism, Wilks' $F(3,58) = 1.19$, $p = .32$. Significant change in prediction across trials was similar to that seen in the previous analyses, Hotelling's $F(3,58) = 20.80$, $p < .001$, $\eta^2 = .52$. Again, performance predictions showed the greatest change at Trial 4 ($M = 9.21$, $SD = 2.88$), in comparison to Trial 3 ($M = 6.81$, $SD = 1.84$), $F(2,60) = 34.39$, $p < .001$, $\eta^2 = .53$, with a significant increase in recall predictions for Trial 2 ($M = 7.33$, $SD = 2.30$) relative to Trial 1 ($M = 6.52$, $SD = 1.94$), $F(2,60) = 5.66$, $p = .006$, $\eta^2 = .16$. The decline in predictions at Trial 3, relative to Trial 2 was not found to be reliable, $F(2,60) = 2.80$, $p = .07$ given the Bonferroni correction establishing alpha at .017.

Comparing the NI young-old, the NI old-old, and the PD groups, as the independent variable, on the dependent variable of checkerboard task performance prediction in a 3 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor, failed to reveal a significant test of levels, $F(2,59) = 1.85$, $p = .17$. This indicates that the performance predictions were not reliably different between the three groups. While the groups did not deviate from parallelism using the Wilks' criterion, $F(4,116) = 2.29$, $p = .06$, predictions changed across trials, Hotelling's $F(2,58) = 6.97$, $p = .002$, $\eta^2 = .19$. Univariate difference contrasts of the marginal means of the Trial factor, using a Bonferroni corrected alpha of .025, showed that the greatest change in predictions of checkerboard performance occurred between Trials 1 ($M = 22.57$, $SD = 9.00$) and 2 ($M = 18.87$, $SD = 4.30$), $F(3,59) = 5.72$, $p = .002$, $\eta^2 = .23$. When averaged across groups

there was little change in predictions between Trials 2 and 3, $F(3,59) = 2.10$, $p = .11$. The means and standard deviations for checkerboard predictions are presented in Table 12.

Table 12

Mean Performance Predictions Across Trials on the Checkerboard Task

Group	n	Trial 1 (SD)	Trial 2 (SD)	Trial 3 (SD)
NI Young-old	22	21.96 (7.18)	20.91 (3.45)	22.14 (2.98)
NI Old-old	20	21.25 (6.38)	18.20 (3.40)	19.10 (3.37)
PD	20	24.55 (12.48)	17.30 (5.16)	16.60 (4.14)

As the test for parallelism was very close to significance, further analyses were conducted using 2 x 3 (Group x Trial) MANOVAs, with repeated measures on the trial factor. The Bonferroni correction established alpha at .017 for these analyses. First, comparing the mean prediction scores on the checkerboard task for the NI young-old and old-old groups failed to reveal a significant age effect with the test of levels, $F(1,40) = 4.36$, $p = .04$. While the NI young-old group predicted that they would place more checkers on the board during the test time ($M = 62.14$, $SD = 7.36$) than the NI old-old group ($M = 55.05$, $SD = 9.88$) the effect was not considered reliable at this level of alpha. The groups were not found to deviate from parallelism using Wilks' criterion, $F(3,39) = .72$, $p = .49$, and they did not show a significant deviation from flatness, Hotelling's $F(2,39) = 4.08$, $p = .03$.

The second MANOVA, comparing the performance predictions of the NI young-old and PD groups on the checkerboard task did not show a significant group effect with prediction scores averaged across trials, $F(1,40) = 2.31$, $p = .14$, and the group means

were not found to deviate from flatness under this stringent level of alpha, Hotelling's $F(2,39) = 4.41$, $p = .02$. Similarly, the groups were not found to deviate from parallelism, Wilks' $F(2,39) = 3.55$, $p = .04$. Post hoc between subjects comparisons of the groups on each trial were conducted, with the Bonferronni alpha correction established at .006. The results showed that while performance predictions on the checkerboard task for the NI young-old and the PD groups were not significantly different on Trial 1, $F(1,40) = .70$, $p = .41$, and Trial 2, $F(1,40) = 7.22$, $p = .01$, predictions on Trial 3 differed significantly, $F(1,40) = 25.12$, $p < .001$, $\eta^2 = .39$. As shown in an inspection of the means in Table 12, the mean predictions of the NI young-old group remained relatively constant across trials, while the predictions of the PD group dropped from a point that was slightly higher than the NI young-old group on Trial 1 to predictions that were significantly lower than the NI young-old group on Trial 3.

A similar MANOVA comparing the checkerboard performance predictions of the NI old-old group and the PD group failed to reveal a significant effect for levels, $F(1,38) = .001$, $p = .98$, and was not found to deviate from parallelism, Wilks' $F(2,37) = 1.70$, $p = .20$. Consistent with the omnibus analysis, group means showed significant change across trials, Hotelling's $F(2,37) = 7.22$, $p = .002$, $\eta^2 = .28$. Difference contrasts of the marginal means, with a Bonferroni correction establishing alpha at .006, found prediction scores to drop significantly between Trial 1 ($M = 22.90$, $SD = 9.93$) and Trial 2 ($M = 17.75$, $SD = 4.34$) for both groups, $F(2,38) = 7.64$, $p = .002$, $\eta^2 = .29$. However, predictions showed little change between Trial 2 and Trial 3 ($M = 17.85$, $SD = 3.93$), $F(2,38) = 1.19$, $p = .32$.

In contrast to the predictions on the checkerboard task, a 3 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor, found that the groups differed in their predictions of performance on the handwriting task, $F(2,59) = 4.72$, $p = .013$, $\eta^2 = .14$. The NI young-old participants ($M = 54.77$, $SD = 15.49$) predicted that they would generate more letters than the NI old-old group ($M = 45.36$, $SD = 8.75$), and both groups expected to have a higher level of performance than the PD group ($M = 41.85$, $SD = 16.76$). However, predictions did not change across Trials using the Hotelling's criterion, $F(2,58) = 2.89$, $p = .06$, and the groups did not vary from parallelism, Wilks' $F(4,116) = .87$, $p = .49$. Means and standard deviations for predictions on the handwriting task are presented in Table 13.

Table 13

Mean Performance Predictions Across Trials on the Handwriting Task

Group	n	Trial 1 (SD)	Trial 2 (SD)	Trial 3 (SD)
NI Young-old	22	18.55 (7.64)	17.86 (5.75)	18.36 (4.69)
NI Old-old	20	15.35 (4.98)	14.16 (2.98)	15.85 (3.72)
PD	20	15.80 (11.78)	12.85 (4.20)	13.20 (4.50)

Follow-up analyses of group differences was conducted comparing the NI young-old and old-old groups, as the independent variable, on dependent variables of handwriting prediction across trials, with a 2 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor. Results showed that the predictions of handwriting performance was significantly related to group membership, $F(1,40) = 5.72$, $p = .02$, $\eta^2 = .14$, with NI young-old group predicting a higher level of performance than the NI old-old group.

Again, the tests for flatness and parallelism were not significant (Hotelling's $F(2,39) = 2.04$, $p = .14$; Wilks' $F(2,39) = .61$, $p = .55$, respectively). Further investigation with similar analyses found that the NI young-old predicted they would produce more handwriting samples than the PD group, $F(1,40) = 6.75$, $p = .013$, $\eta^2 = .14$. Again, there was no change across trials using the Hotelling's criterion, $F(2,39) = 1.00$, $p = .38$, and the test for parallelism was not significant using Wilks' criterion, $F(2,39) = .38$, $p = .69$. Comparing the NI old-old group with the PD group failed to show a significant difference in handwriting prediction, $F(1,38) = .69$, $p = .41$. However, predictions showed significant change across trials when averaged over these two groups, Hotelling's $F(2,37) = 4.66$, $p = .016$, $\eta^2 = .20$, with the greatest degree of change shown between Trials 2 and 3, $F(2,37) = 5.69$, $p = .007$, $\eta^2 = .23$. The mean predictions increased for Trial 3 ($M = 14.53$, $SD = 4.29$) relative to Trial 2 ($M = 13.50$, $SD = 3.65$). A Bonferroni corrected alpha was established at .025. Comparison of Trials 1 and 2 showed they were substantively similar, $F(2,38) = 1.35$, $p = .27$. The test for parallelism was not significant using the Wilks' criterion, $F(2,37) = 1.99$, $p = .15$. As seen in Table 13, the means of the NI old-old group and the PD group were similar, with lower predictions in Trial 2 than Trial 3.

Performance Postdictions. In contrast to the prediction scores for verbal fluency, a 3 x 4 (Group x Trial) MANOVA of the postdiction scores, with repeated measures on the Trial factor, revealed differences among the groups, $F(2,59) = 3.92$, $p = .025$, $\eta^2 = .12$. Specifically, verbal fluency postdiction means were highest in the NI young-old group ($M = 67.18$, $SD = 43.72$), with the NI old-old group ($M = 58.65$, $SD = 25.02$) postdicting

higher levels of performance than the PD group (M = 48.10, SD = 24.64) across trials. Postdiction profiles deviated significantly from flatness, Hotelling's $F(3,57) = 6.183$, p = .001, $\eta^2 = .25$. However, the groups were not found to deviate from parallelism, Wilks' $F(6,114) = .18$, $p = .98$. Given the more stringent alpha, Bonferroni adjusted to .017, planned hypothesis testing through difference contrasts of the marginal means of the Trial factor failed to reveal the significant differences between trials. A trend toward significance was indicated between Trials 2 (M = 12.34, SD = 6.53) and 3 (M = 13.58, SD = 7.23), $F(3,59) = 3.41$, $p = .023$, with little change in postdiction scores apparent between Trials 1 (M = 12.82, SD = 6.42) and 2, $F(3,59) = .42$, $p = .74$, and Trials 3 and 4 (M = 14.61, SD = 6.75), $F(3,59) = 1.28$, $p = .29$. Means and standard deviations for each group are presented in Table 14.

Table 14

Mean Performance Postdictions Across Trials of Verbal Fluency

Group	n	Trial 1 (SD)	Trial 2 (SD)	Trial 3 (SD)	Trial 4 (SD)
NI young-old	22	15.00 (8.30)	14.41 (6.93)	16.14 (8.96)	17.18 (8.00)
NI old-old	20	13.05 (4.75)	12.85 (6.45)	13.70 (5.81)	14.80 (5.47)
PD	20	10.20 (4.54)	9.55 (5.36)	10.65 (5.33)	11.60 (5.35)
Combined NI	42	14.07 (6.84)	13.67 (6.67)	14.98 (7.64)	16.05 (6.94)

A 2 x 4 (Group x Trial) MANOVA, with repeated measures on the Trial factor, was conducted to compare the verbal fluency postdiction scores of the NI young-old and the NI old-old groups. The levels test failed to show a difference between the groups, $F(1,40) = 1.05$, $p = .31$. As with the previous analysis, the effect for parallelism was not

significant, Wilks' $F(3,38) = .24$, $p = .87$. A test of flatness found that postdiction scores changed across trials, Hotelling's $F(3,38) = 4.44$, $p = .009$, $\eta^2 = .26$. Planned difference contrasts of the marginal means for the Trial factor, with a Bonferroni correction establishing alpha at .017, failed to show a significant effect for the three comparisons under this stringent level of alpha, Trial 1 and Trial 2: $F(2,40) = .26$, $p = .77$; Trial 2 and Trial 3: $F(2,40) = 3.46$, $p = .04$; Trial 3 and Trial 4: $F(2,40) = 1.56$, $p = .22$. Inspection of the means in Table 14 shows that the performance postdictions for verbal fluency are relatively stable across trials for the combined NI group, with a modest increase for the semantic condition on Trial 4. In contrast, a 2 x 4 (Group x Trial) MANOVA, with repeated measures on the Trial factor, found the verbal fluency postdictions of the combined NI and the PD groups to be related to group membership, $F(1,60) = 6.56$, $p = .013$, although the size of the effect was small, $\eta^2 = .10$. The postdictions of the combined NI group ($M = 63.12$, $SD = 35.88$) were higher than those of the PD group ($M = 48.10$, $SD = 24.64$). The test for flatness also showed that postdictions changed across trials, Hotelling's $F(3,58) = 5.20$, $p = .003$, $\eta^2 = .21$. Difference contrasts of the marginal means for the Trial factor, with a Bonferroni correction establishing alpha at .017, showed similar postdictions for Trials 1 and 2, $F(2,60) = .59$, $p = .56$, and Trial 3 and 4, $F(2,60) = 1.95$, $p = .15$. However, a significant change in postdictions was evident between Trial 2 and 3, $F(2,60) = 4.74$, $p = .012$, $\eta^2 = .14$, with the mean postdiction scores showing a slight increase (Trial 2: $M = 12.34$, $SD = 6.53$; Trial 3: $M = 13.58$, $SD = 7.23$).

Postdiction of performance on the CCST, with the three groups as the independent variable, was also shown to relate significantly to group membership when analysed with a

one-way ANOVA, $F(2,59) = 6.40$, $p = .003$, $\eta^2 = .18$. The NI young-old ($M = 5.62$, $SD = 1.46$) postdicted a higher level of performance than the NI old-old group ($M = 3.90$, $SD = 1.41$). Somewhat surprisingly, the postdictions of the PD group ($M = 4.20$, $SD = 2.09$) also appeared to be higher than those of the NI old-old group. Post hoc Tukey's pairwise comparisons, with a Bonferroni correction establishing alpha at .017, found a significant difference between the postdictions of the NI young-old and old-old groups, $HSD = -1.72$, $p = .004$. However, the contrasts between the NI young-old and the PD groups and the NI old-old and the PD groups were not reliably different ($HSD = -1.42$, $p = .02$; $HSD = .31$, $p = .83$, respectively).

Profile analyses were conducted with a 3 x 4 (Group x Trial) MANOVA, with repeated measures on the Trial factor, to compare the dependent variables of postdiction scores on the CVLT of the NI young-old, old-old, and PD groups. The test of levels found the postdiction scores of the groups to differ, $F(2,59) = 4.97$, $p = .01$, $\eta^2 = .14$. While the postdictions of the NI young-old ($M = 32.43$, $SD = 9.12$) and the old-old groups ($M = 30.60$, $SD = 8.58$) were similar, they were higher than the postdiction estimates of the PD group ($M = 24.95$, $SD = 5.51$). The groups did not deviate from parallelism, Wilks' $F(6,114) = .49$, $p = .82$. As with the prediction scores, the test for flatness with the trials representing memory conditions, showed significant change in postdiction estimates across trials, Hotelling's $F(3,57) = 50.71$, $p < .001$, $\eta^2 = .73$. Planned univariate difference contrasts of the marginal means of the Trial factor, with a Bonferroni correction establishing alpha at .017, found the greatest change in CVLT postdiction occurring between Trials 3 (delayed recall condition $M = 6.58$, $SD = 2.32$) and

4 (recognition condition: M = 10.06, SD = 2.91), F(3,59) = 36.82, p < .001, η^2 = .65; and Trials 1 (learning trial M = 5.85, SD = 2.44) and 2 (learning trial M = 6.95, SD = 2.36), F(3,59) = 6.97, p < .001, η^2 = .26. Contrasts of Trials 2 and 3 were not significant, F(3,59) = 1.74, p = .17. The means and standard deviations for each group across trials are presented in Table 15.

Table 15

Mean Performance Postdictions Across Trials of the California Verbal Learning Test

Group	n	Trial 1 (SD)	Trial 2 (SD)	Trial 3 (SD)	Trial 4 (SD)
NI young-old	22	6.67 (2.21)	7.71 (2.33)	7.48 (2.24)	10.57 (3.33)
NI old-old	20	5.90 (2.27)	7.10 (2.40)	6.95 (2.04)	10.65 (3.22)
PD	20	4.90 (2.61)	5.95 (2.06)	5.21 (2.12)	8.90 (1.59)
Combined NI	42	6.30 (2.25)	7.42 (2.36)	7.22 (2.14)	10.61 (3.24)

Follow-up analyses to further assess group differences in postdiction of CVLT performance were conducted. The first profile analysis compared the NI young-old and old-old groups with a 2 x 4 (Group x Trial) MANOVA, with repeated measures on the Trial factor. A test of levels found that these two groups did not differ in their postdiction scores, F(1,40) = .48, p = .51. Consistent with the pattern of prediction scores on the CVLT, the test for flatness revealed a change in scores across trials, Hotelling's F(3,38) = 43.40, p < .001, η^2 = .77, with difference contrasts showing the greatest magnitude of change occurred between Trials 3 (delayed free recall M = 7.22, SD = 2.14) and 4 (recognition M = 10.61, SD = 3.24), F(2,40) = 41.46, p < .001, η^2 = .67; and Trials 1 and 2 (immediate free recall Trial 1 M = 5.85, SD = 2.44; Trial 2 M = 6.95, SD = 2.36),

$F(2,40) = 11.75$, $p < .001$, $\eta^2 = .37$. Consistent with the omnibus analysis, the contrast of Trials 2 and 3 failed to reveal significant change in postdiction scores, $F(2,40) = .43$, $p = .66$. These results indicate that the NI participants felt their performance improved on the second free recall learning trial, relative to the first, and that they had recognized more words during Trial 4, than they had been able to recall in Trial 3.

A similar analysis was conducted to compare the postdiction scores of the combined NI and the PD groups. The results found postdiction scores of these two groups to differ, $F(1,60) = 9.44$, $p = .003$, $\eta^2 = .14$. The average postdictions of CVLT performance were higher for the combined NI group ($M = 31.56$, $SD = 8.80$) than they were for the PD group ($M = 24.95$, $SD = 5.51$). A test of flatness found postdictions of CVLT to vary across trials, $F(3,58) = 43.90$, $p < .001$, $\eta^2 = .69$, with difference contrasts showing the greatest difference between the delayed free recall trial and the recognition trial, $F(2,60) = 55.35$, $p < .001$, $\eta^2 = .65$. Once again, estimates of performance on Trials 1 and 2 differed significantly, $F(2,60) = 10.58$, $p < .001$, $\eta^2 = .26$. The contrasts of Trials 2 and 3 were not significant, $F(2,60) = 2.64$, $p = .08$. As expected given the nature of these memory trials, participants felt they had recalled more words on the second free recall trial than on the first, and again, they reported that they had recognized more words than they were able to recall on the delayed free recall trial. While examination of the means in Table 15 suggests a slight drop in postdiction estimates for the delayed free recall trial (Trial 3), relative to the second learning trial (Trial 2), the difference was not shown to be statistically significant in these analyses.

A profile analysis of the postdiction scores for performance on the checkerboard task was conducted with a 3 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor and the NI young-old, old-old, and PD groups as the independent variable. Scores were found to deviate significantly from parallelism, $F(4,116) = 3.05$, $p = .02$, $\eta^2 = .19$. Postdictions were significantly different for the NI young-old, old-old, and PD groups, $F(2,59) = 19.90$, $p < .001$, $\eta^2 = .40$. The NI young-old group ($M = 62.14$, $SD = 7.36$) estimated that they had placed more checkers on the board than the NI old-old group ($M = 55.05$, $SD = 9.88$), and both NI groups reported a higher level of performance than the PD group ($M = 45.20$, $SD = 8.84$). Tests of flatness found scores also differed across trials, Hotelling's $F(2,58) = 28.02$, $p < .001$, $\eta^2 = .49$. An inspection of the means in Table 16 suggests that the postdiction estimates of the NI groups increased across trials, while the estimates of the PD group showed little variability. Further analyses were conducted to investigate the significant effects.

Table 16

Mean Performance Postdictions Across Trials of the Checkerboard Task

Group	n	Trial 1 (SD)	Trial 2 (SD)	Trial 3 (SD)
NI young-old	22	18.64 (2.42)	21.41 (2.72)	22.09 (3.22)
NI old-old	20	16.95 (3.30)	18.95 (3.36)	19.15 (3.79)
PD	20	14.40 (2.95)	14.95 (3.40)	15.85 (3.28)
Combined NI	42	17.83 (2.96)	20.24 (3.25)	20.69 (3.76)

Follow-up analysis, using a 2 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor, was conducted comparing the NI young-old and old-old

participants on the checkerboard postdiction scores. The groups did not deviate from parallelism, Wilks' $F(2,39) = 1.09$, $p = .35$, however, postdiction scores varied by group, $F(1,40) = 7.04$, $p = .011$, $\eta^2 = .15$. The NI young-old group ($M = 62.14$, $SD = 7.36$) had higher postdiction estimates on the checkerboard task than the NI old-old group ($M = 55.05$, $SD = 9.88$). As with the previous analysis, the test for flatness was significant, Hotelling's $F(2,39) = 30.70$, $p < .001$, $\eta^2 = .61$. Planned difference contrasts of the marginal means for the Trial factor, with a Bonferroni correction establishing alpha at .025, showed that postdiction estimates for both groups were higher in Trial 2 ($M = 20.24$, $SD = 3.25$) than in Trial 1 ($M = 17.83$, $SD = 2.96$), $F(2,40) = 32.38$, $p < .001$, $\eta^2 = .61$. Postdiction scores in Trial 2 and Trial 3 were found to be similar, $F(2,40) = 1.75$, $p = .19$.

As the performance postdictions of the NI groups were age dependent, each group was independently compared to the PD group with 2 x 3 (Group x Trial) MANOVAs. A similar pattern of results was found in the analysis comparing the checkerboard postdiction scores of the NI young-old and PD groups, with the exception that the groups were found to deviate significantly from parallelism, Wilks' $F(2,39) = 5.42$, $p = .008$, $\eta^2 = .22$. The estimates of the NI young-old group increased across trials while the estimates of the PD group remained relatively stable, as shown in Table 16. Postdiction scores varied by group, $F(1,40) = 45.85$, $p < .001$, $\eta^2 = .53$. The NI young-old group provided higher postdiction estimates than the PD group ($M = 45.20$, $SD = 8.84$) over the three trials. Postdiction scores also varied across trials, Hotelling's $F(2,39) = 17.82$, $p < .001$, $\eta^2 = .47$. Bonferroni adjusted alpha was established at .005 for the follow-up analyses of the

parallelism effect. Independent one-way ANOVAs were conducted for each trial of the checkerboard postdiction scores, with the NI young-old and the PD groups as the independent variables, to further examine the interaction effect. Each analysis found the groups to differ significantly on the dependent variable (Trial 1: $F(1,40) = 26.12$, $p < .001$, $\eta^2 = .40$; Trial 2: $F(1,40) = 46.71$, $p < .001$, $\eta^2 = .54$; Trial 3: $F(1,40) = 38.64$, $p < .001$, $\eta^2 = .49$). As shown in Table 16, the NI young-old group had higher postdiction estimates on each trial of the checkerboard task than the PD group. Profile analyses using one-way ANOVAs, with repeated measures on the Trial factor, were conducted separately for the NI young-old and the PD groups. Results showed significant deviations from flatness for the NI young-old group, Hotelling's $F(2,20) = 24.00$, $p < .001$, $\eta^2 = .71$. However, the flatness test was not significant at the established alpha level of .005 for the PD group, Hotelling's $F(2,18) = 5.02$, $p = .019$. Planned hypothesis testing of the marginal means for the Trial factor with difference contrasts found the postdiction scores for the checkerboard task for the NI young-old participants increased significantly between Trial 1 and Trial 2, $F(1,21) = 49.43$, $p < .001$, $\eta^2 = .70$, as suggested in Table 16. However, difference contrasts of Trials 2 and 3 found postdictions to remain constant across these two trials, $F(1,21) = 2.80$, $p = .11$.

A profile analysis conducted with a 2 x 3 (Group x Trial) MANOVA, with the NI old-old and the PD groups as the independent variable, and repeated measures on the Trial factor, also found the checkerboard postdiction scores to be related to group membership, $F(1,38) = 11.05$, $p = .002$, $\eta^2 = .23$. Postdictions of the NI old-old participants were found to be significantly higher than those of the PD participants. While the scores for the

two groups did not deviate from parallelism, Wilks' $F(2,37) = 2.03$, $p = .145$, tests of flatness showed change across trials, Hotelling's $F(2,37) = 13.39$, $p < .001$, $\eta^2 = .42$. Planned difference contrasts of the marginal means for the Trial factor, with Bonferroni corrections establishing alpha at .025, showed that postdictions for Trial 2 ($M = 16.95$, $SD = 3.90$) were higher than Trial 1 ($M = 15.68$, $SD = 3.35$), $F(2,38) = 8.30$, $p = .001$, $\eta^2 = .30$. The contrasts for Trial 2 and Trial 3 were not significant, $F(2,38) = 2.50$, $p = .10$.

Overall, postdiction estimates of performance on the checkerboard task were significantly different for each of the three groups of participants. The NI young-old and old-old groups estimated a higher level of performance than the PD group, and estimates increased significantly between first and the second trial for the NI groups. Postdiction estimates of the PD group showed insignificant increases over the three trials.

A 3 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor, was conducted to compare the postdictions of handwriting performance of the NI young-old, old-old, and PD groups. Tests of levels found postdiction scores differed by group, $F(2,59) = 9.73$, $p < .001$, $\eta^2 = .25$ and the test for flatness showed significant change across trials, Hotelling's $F(2,58) = 17.47$, $p < .001$, $\eta^2 = .38$. As expected, the NI young-old group ($M = 52.82$, $SD = 12.82$) estimated that they had produced more backward *hs* than the NI old-old group ($M = 43.55$, $SD = 9.42$), and both groups had higher estimates than the PD group ($M = 37.25$, $SD = 11.91$). Planned difference contrasts of the marginal means for the Trial factor, with a Bonferroni correction establishing alpha at .025, found the scores to change significantly between Trial 1 ($M = 13.63$, $SD = 4.41$) and 2 ($M = 15.27$, $SD = 4.63$), $F(3,59) = 7.00$, $p < .001$, $\eta^2 = .31$, and Trial 2 and 3 ($M = 15.90$, $SD =$

4.75), $F(3,59) = 4.23$, $p = .009$, $\eta^2 = .18$. Handwriting postdiction scores did not deviate from parallelism, Wilks' $F(4,114) = .52$, $p = .72$. An inspection of the means in Table 17 shows that postdiction scores increased across trials for all groups.

Table 17

Mean Performance Postdictions Across Trials of the Handwriting Task

Group	n	Trial 1 (SD)	Trial 2 (SD)	Trial 3 (SD)
NI young-old	22	16.18 (4.76)	17.91 (4.69)	18.73 (4.51)
NI old-old	20	13.00 (3.42)	14.90 (3.37)	15.65 (3.53)
PD	20	11.45 (3.59)	12.75 (4.27)	13.05 (4.42)
Combined NI	42	14.67 (4.43)	16.48 (4.34)	17.26 (4.31)

To further examine group differences and changes in handwriting postdiction estimates across trials in the NI young-old and old-old groups a 2 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor, was conducted. The groups did not deviate from parallelism, Wilks' $F(2,39) = .024$, $p = .98$. A test of levels showed that the NI young-old group had higher postdiction estimates than the NI old-old group, $F(1,40) = 7.00$, $p = .012$, $\eta^2 = .15$, as suggested by an inspection of the marginal means presented earlier. Postdiction scores also changed across trials, Hotelling's $F(2,39) = 13.94$, $p < .001$, $\eta^2 = .42$. Planned difference contrasts of the marginal means in the Trial factor, with a Bonferroni correction establishing alpha at .025, found scores to increase between Trial 1 ($M = 14.67$, $SD = 4.43$) and 2 ($M = 16.48$, $SD = 4.34$), $F(2,40) = 6.50$, $p = .004$, $\eta^2 = .25$, and between Trial 2 and 3 ($M = 17.26$, $SD = 4.31$), $F(2,40) = 6.41$, $p = .004$, $\eta^2 = .24$.

A 2 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor, was also conducted to compare the handwriting postdiction scores of the NI young-old and the PD groups. A test of levels found group differences in postdictions scores to be significant, $\underline{F}(1,40) = 16.52$, $\underline{p} < .001$, $\eta^2 = .24$, with the scores of the NI young-old group higher than those of the PD group. Postdiction scores changed across trials, Hotelling's $\underline{F}(2,39) = 9.55$, $\underline{p} < .001$, $\eta^2 = .33$. Planned univariate difference contrasts of the marginal means of the Trial factor, with a Bonferroni correction establishing alpha at .025, showed that scores increased in Trial 2 ($\underline{M} = 15.45$, $\underline{SD} = 5.15$) as compared with Trial 1 ($\underline{M} = 13.93$, $\underline{SD} = 4.83$), $\underline{F}(2,40) = 5.77$, $\underline{p} = .006$, $\eta^2 = .22$. However, contrasts between Trial 2 and Trial 3 found the postdiction scores remained stable across these two occasions, $\underline{F}(2,40) = 3.26$, $\underline{p} = .049$ when the scores were collapsed across these two groups. The groups did not deviate from parallelism, Wilks' $\underline{F}(2,39) = .76$, $\underline{p} = .476$.

A similar analysis comparing the NI old-old and the PD group failed to find significant group differences in handwriting postdiction scores, $\underline{F}(1,38) = 3.44$, $\underline{p} = .07$. As with the previous analysis, tests of flatness found the postdiction scores changed across trials, Hotelling's $\underline{F}(2,37) = 13.20$, $\eta^2 = .42$, with the means of Trial 2 ($\underline{M} = 13.83$, $\underline{SD} = 3.95$) significantly higher than those of Trial 1 ($\underline{M} = 12.23$, $\underline{SD} = 3.55$), $\underline{F}(2,38) = 10.28$, $\underline{p} < .001$, $\eta^2 = .35$. However, scores did not change between Trials 2 and 3, $\underline{F}(2,38) = 3.27$, $\underline{p} = .049$. Using the Wilks' criteria the groups were not found to deviate from parallelism, $\underline{F}(2,37) = .90$, $\underline{p} = .42$, indicating that the slope of the postdictions across trials was similar for these two groups.

In summary, postdiction estimates of performance on the handwriting task were higher for the NI young-old group than for the NI old-old and the PD groups. As expected, the PD group estimated a lower level of performance than either of the NI groups. The estimates of the NI groups increased consistently across trials. However, those of the PD group only showed a significant increase between Trials 1 and 2, remaining relatively stable on Trial 3. Variability in postdiction estimates across trials was not found to be significant with tests of parallelism.

Relation between Performance Prediction and Postdiction Scores. The relations between predictions and postdictions of performance were assessed through Pearson product moment correlational analyses. The prediction raw score for each trial, within each measure, was correlated with the corresponding score for the postdiction task for each group. It was expected that the magnitude of the correlations would increase with each trial, with the correlation between Trial 3 predictions and postdictions showing the greatest magnitude. Bonferroni corrections established the alpha level at .001 to reduce the probability of Type I error. As shown in Table 18, the correlations generally remained stable or improved across trials, with the exception of the prediction and postdiction correlations for the CVLT in the PD group. In this group the correlations dropped across the free recall trials from $r = .58$ on Trial 1 to $r = .23$ on Trial 3, with no correlation between prediction and postdiction scores, $r = -.00$, for Trial 4, the recognition trial.

Generally, the pattern of correlations of predictions with the postdictions from the previous trial (e.g., prediction Trial 2 with postdiction Trial 1) were similar to the within trial prediction and postdiction correlations. Specifically, correlations for verbal fluency

were similar to same trial predictions and postdictions, ranging from $\underline{r} = .75$ for the correlation of prediction 4 with postdiction 3 in the PD group, to $\underline{r} = .92$ between prediction 2 and postdiction 1 in the NI young-old group. CVLT time-lagged correlations which ranged from $\underline{r} = .37$ between prediction 4 (recognition trial) and postdiction 3 for the PD group, to $\underline{r} = .86$ for prediction 2 with postdiction 1 for the NI young-old group. Correlations for the checkerboard and handwriting tasks ranged from $\underline{r} = .21$ between prediction 2 and postdiction 1 for the NI old-old group on the handwriting task to $\underline{r} = .96$ between prediction 3 and postdiction 2 for the NI young-old group on the handwriting task.

Table 18

Same Trial Prediction and Postdiction Correlations

Measure	Trial 1	Trial 2	Trial 3	Trial 4
		NI Young-Old ($\underline{n} = 22$)		
Verbal Fluency	.90*	.80*	.83*	.86*
CCST	.65*	---	---	---
CVLT	.64*	.77*	.85*	.58
Checkerboard	.13	.63	.65*	---
Handwriting	.51	.60	.93*	---
		NI Old-Old ($\underline{n} = 20$)		
Verbal Fluency	.50	.85*	.88*	.83*
CCST	.37	---	---	---
CVLT	.52	.78*	.69*	.63
Checkerboard	-.01	.69*	.71*	---
Handwriting	-.21	.35	.59	---

Table 18 continued

Measure	Trial 1	Trial 2	Trial 3	Trial 4
		Parkinson's (n = 20)		
Verbal Fluency	.55	.82*	.83*	.83*
CCST	.91*	---	---	---
CVLT	.58	.48	.23	.00
Checkerboard	.04	.41	.70*	---
Handwriting	.19	.76*	.89*	---
		Combined NI (n = 42)		
Verbal Fluency	.79*	.79*	.84*	.84*
CCST	.29	---	---	---
CVLT	.60*	.78*	.79*	.65*
Checkerboard	.07	.71*	.74*	---
Handwriting	.36	.59*	.83*	---

Note. CCST = California Card Sorting Test; CVLT = California Verbal Learning Test.

* $p \leq .001$.

Prediction Accuracy. The relation between predicted scores and actual performance scores was first analysed through Pearson product moment correlations for each of the three groups, NI young-old, NI old-old, and PD. As seen in Table 19, the pattern of correlations was similar across groups, increasing for the motor tasks while showing greater inter-trial variability for verbal fluency and the CVLT. Specifically, correlations dropped on the second trial of the verbal fluency task for the NI young-old

group, and the correlations on the fourth trial of the CVLT were lower for all groups than the previous trial.

Table 19

Prediction and Performance Correlations Within Trials

Measure	Trial 1	Trial 2	Trial 3	Trial 4
		NI Young-Old (n = 22)		
Verbal Fluency	.56	.23	.47	.50
CCST	.12	---	---	---
CVLT	.62	.71*	.76*	.25
Checkerboard	.28	.42	.61	---
Handwriting	.60	.69	.85*	---
		NI Old-Old (n = 20)		
Verbal Fluency	.13	.64	.56	.67*
CCST	-.29	---	---	---
CVLT	.41	.52	.48	.28
Checkerboard	-.01	.66	.86*	---
Handwriting	-.07	.33	.67*	---
		Parkinson's (n = 20)		
Verbal Fluency	.28	.48	.71*	.31
CCST	.59	---	---	---
CVLT	-.11	.17	.33	.00
Checkerboard	.01	.42	.69*	---
Handwriting	.23	.66	.78*	---

Table 19 continued

Measure	Trial 1	Trial 2	Trial 3	Trial 4
		Combined NI (n = 42)		
Verbal Fluency	.38	.34	.49*	.65*
CCST	-.18	---	---	---
CVLT	.51*	.61*	.64*	.25
Checkerboard	.16	.60*	.79*	---
Handwriting	.41	.64*	.81*	---

Note. CCST = California Card Sorting Test; CVLT = California Verbal Learning Test.

* $p \leq .001$.

The second method for analyzing prediction accuracy was to examine group differences using profile analysis for each task, with the prediction accuracy scores of that task as the dependent variable. Specifically, for the purpose of these analyses, accuracy scores were derived by dividing the prediction score for each task by the actual performance score. Perfect accuracy of performance prediction would result in an accuracy score of 1.0, whereas an accuracy score of greater or less than 1.0 would indicate an over or an underestimate of performance (McGlynn & Kaszniak, 1991).

Profile analysis was used to compare the three groups on the prediction accuracy of phonemic verbal fluency performance across three trials. A 3 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor and the NI young-old, old-old, and PD groups as the independent variable, was conducted. The profiles did not deviate significantly from parallelism using the Wilks' criterion, $F(4,116) = 1.64$, $p = .17$. A test

of levels showed that prediction accuracy did not vary across groups on the phonemic word fluency task, $F(2,59) = 1.81$, $p = .17$. However, tests of flatness using the Hotelling's criterion indicated that the accuracy of the predictions increased across trials, $F(2,58) = 7.15$, $p = .002$, $\eta^2 = .20$. Univariate difference contrasts of marginal means for the Trial factor, using a Bonferroni corrected alpha of .025, showed that while the prediction accuracy for Trial 1 ($M = 1.48$, $SD = 1.40$) and Trial 2 ($M = 1.42$, $SD = .92$) were similar, $F(3,59) = .26$, $p = .85$, the accuracy of predictions improved between Trial 2 and Trial 3 ($M = 1.03$, $SD = .44$), $F(3,59) = 6.91$, $p < .001$, $\eta^2 = .26$. The means and standard deviations for the groups on each trial are presented in Table 20.

Table 20

Mean Prediction Accuracy Scores for Verbal Fluency

		Trial			
Group	n	1	2	3	4
NI Young-Old	22	1.32	1.39	1.06	.80
(SD)		(.76)	(.93)	(.57)	(.30)
NI Old-Old	20	1.22	1.12	1.01	.87
(SD)		(.84)	(.42)	(.38)	(.26)
Parkinson's	20	1.92	1.76	1.01	.98
(SD)		(2.15)	(1.18)	(.37)	(.39)
Combined NI	42	1.27	1.26	1.04	.84
(SD)		(.79)	(.73)	(.48)	(.28)

Note. Scores closer to 1 indicate a higher level of accuracy, with scores < 1 indicating underestimates of performance and scores > 1 indicating overestimates of performance.

An ANOVA analysing group differences in prediction accuracy of the semantic verbal fluency condition failed to support the hypothesis that accuracy was related to group membership, $F(2,59) = .74$, $p = .48$. As shown by the means in Table 20, all groups underestimated their performance on the semantic condition of the word fluency task, whereas prediction estimates on the phonemic conditions were all overestimates of performance.

A comparison of the group means for the three groups on Trial 1 of CCST failed to find reliable differences in prediction accuracy between the groups, $F(2,57) = .16$, $p = .87$. The differences in prediction accuracy between the groups were small, with the NI young-old group ($M = 1.34$, $SD = .97$) showing a slightly higher level of accuracy than the NI old-old group ($M = 1.43$, $SD = 1.40$), and both groups showing a higher level of accuracy than the PD group ($M = 1.53$, $SD = .72$). The number of participants in the NI old-old group and the PD were reduced to 19 for this measure as one participant in each group failed to generate a score above zero for correct sorts on Trial 1 of the CCST.

Profiles of the prediction accuracy for the NI young-old, old-old, and the PD groups were compared on the CVLT across 3 trials. As the memory skills demanded in the recognition trial differed from the free recall trials, analysis of the prediction data from that trial will be conducted separately. A 3 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor and the NI young-old, old-old and PD groups as the independent variable, was conducted. The profiles did not deviate significantly from parallelism using the Wilks' criterion, $F(4,114) = .37$, $p = .83$. A test of levels supported the hypothesis that the level of prediction accuracy would vary across groups, $F(2,58) =$

3.70, $p = .031$, although the effect size was small, $\eta^2 = .11$. When the accuracy scores were averaged across trials of free recall, all groups overestimated their performance. The NI young-old ($M = 3.13$, $SD = .50$) and the NI old-old ($M = 3.57$, $SD = 1.85$) groups only slightly overpredicted their performance across the three trials, with prediction accuracy averaging 1.04 and 1.19 per trial, respectively. In contrast, the over-predictions of the PD group ($M = 4.40$, $SD = 1.83$) were greater, averaging 1.47 per trial. Tests of flatness, using the Hotelling's criterion, showed a main effect for the Trial factor, $F(2,57) = 6.37$, $p = .003$, $\eta^2 = .18$. Univariate comparisons of the marginal means for the Trial factor, with a Bonferroni corrected alpha at .025, indicated that prediction accuracy of Trial 1 ($M = 1.54$, $SD = 1.21$) and Trial 2 ($M = 1.04$, $SD = .43$) were significantly different, $F(3,58) = 4.23$, $p = .009$, $\eta^2 = .18$. However, the prediction accuracy of Trial 2 and Trial 3 ($M = 1.13$, $SD = .45$) did not differ significantly, $F(3,58) = .91$, $p = .44$. As seen in individual group scores for each trial presented in Table 21, prediction accuracy on the CVLT generally increased in Trial 2, compared with Trial 1, and then remained relatively stable in Trial 3.

Table 21

Mean Prediction Accuracy Scores for the California Verbal Learning Test Across Trials

		Trial		
Group	n[a]	1	2	3
NI Young-Old	22	1.22	.93	.99
(SD)		(.32)	(.23)	(.22)
NI Old-Old	20	1.53	.94	1.09
(SD)		(1.57)	(.28)	(.46)
Parkinson's	20	1.91	1.24	1.33
(SD)		(1.36)	(.63)	(.57)
Combined NI	42	1.37	.94	1.04
(SD)		(1.10)	(.25)	(.35)

Note. Scores closer to 1 indicate a higher level of accuracy with scores < 1 indicating underestimates of performance and scores > 1 indicating an overestimate of performance.

[a]n = 19 in Trial 3 for the PD group.

Comparing the profiles of the young-old and old-old NI groups, using a 2 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor and prediction accuracy on the CVLT as the dependent variables, showed that the prediction accuracy was similar for these two groups, $F(1,40) = 1.11$, $p = .30$. However, tests of flatness showed a significant effect for Trial using Hotelling's criterion, $F(2,39) = 5.43$, $p = .008$, $\eta^2 = .22$. The profiles did not vary from parallelism, using the Wilks' criterion $F(2,39) = .83$, $p = .45$. Univariate differences contrasts of the marginal means, with a Bonferonni correction establishing alpha at .025, showed a higher level of prediction accuracy for

Trial 2 (M = .94, SD = .25), compared with Trial 1 (M = 1.37, SD = 1.10), $F(2,40)$ = 4.15, p = .023, η^2 = .17. Prediction accuracy remained constant for Trial 2 and Trial 3 (M = 1.04, SD = .35), $F(2,40)$ = 1.58, p = .22.

Similar analyses, comparing the combined NI group with the PD participants, found the groups to differ significantly in the level of prediction accuracy on the CVLT, $F(1,59)$ = 6.54, p = .013, η^2 = .10. The predictions of the combined NI group (M = 3.34, SD = 1.33) were more accurate over the three trials than those of the PD group (M = 4.40, SD = 1.83). Tests of flatness, using the Hotelling's criterion, also supported the hypothesis that prediction accuracy would vary across trials, $F(2,58)$ = 6.24, p = .004, η^2 = .18. The profiles of the groups did not vary from parallelism, Wilks' $F(2,58)$ = .29, p = .75. Univariate comparison of the marginal means for Trial in the C Matrix, showed a higher level of prediction accuracy in Trial 2 (M = 1.04, SD = .43) compared with Trial 1 (M = 1.54, SD = 1.21), using a Bonferroni corrected alpha of .025, $F(2,59)$ = 6.01, p = .004, η^2 = .17. Trial 3 did not differ significantly from Trial 2, $F(2,59)$ = 1.22, p = .30. In summary, the pattern of results showed that prediction accuracy on this list-learning task was not influenced by age, however, decrements associated with PD were evident. All participants showed an improvement in their ability to accurately predict performance after the first trial and this level of accuracy was maintained for Trial 3.

Group differences on prediction accuracy for Trial 4 of the CVLT, assessing list-word recognition as opposed to the free recall of Trials 1 to 3, was assessed with a one-way ANOVA, with prediction accuracy as the dependent variable and the NI young-old, old-old, and PD groups as the independent variable. Results did not support the

hypothesis that the prediction accuracy of the groups would vary. Specifically, the NI young-old (M = .78, SD = .20), old-old (M = .70, SD = .24), and PD (M = .67, SD = .22) participants all showed similar levels of prediction accuracy on the recognition trial (Trial 4) of the CVLT, $F(2,59) = 1.28$, $p = .29$, generally under-estimating their ability to recognize list-words.

Profile analysis comparing the NI young-old, old-old, and PD groups on the prediction accuracy for the checkerboard task was conducted with a 3 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor. The test of levels showed that the groups differed in their ability to accurately predict the number of checkers they could place within the time limit, $F(2,59) = 6.00$, $p = .004$, $\eta^2 = .17$. With accuracy scores summed over the three trials, the performance estimates of the NI young-old group (M = 3.11, SD = .45) were slightly more accurate than that of the NI old-old participants (M = 3.26, SD = .49). The accuracy level of both NI groups was higher than that of the PD group (M = 3.99, SD = 1.39). The test of flatness also supported the hypothesis that the accuracy of prediction would improve across trials, Hotelling's $F(2,58) = 11.00$, $p < .001$, $\eta^2 = .28$, although the profiles were found to deviate significantly from parallelism, Wilks' $F(4,116) = 2.69$, $p = .04$, $\eta^2 = .16$. Further analyses were conducted to investigate this interaction. Group means and standard deviations for each trial are presented in Table 22.

Table 22

Mean Prediction Accuracy Scores for the Checkerboard Task Across Trials

		Trial		
Group	n	1 (SD)	2 (SD)	3 (SD)
NI Young-Old	22	1.11 (.34)	.99 (.17)	1.01 (.12)
NI Old-Old	20	1.28 (.44)	.97 (.14)	1.07 (.08)
Parkinson's	20	1.79 (1.04)	1.15 (.37)	1.05 (.21)
Combined NI	42	1.19 (.40)	.98 (.16)	1.01 (.10)

Note. Scores closer to 1 indicate a higher level of accuracy with scores < 1 indicating underestimates of performance and scores > 1 indicating an overestimate of performance.

The profiles of the NI young-old and old-old participants were compared on prediction accuracy for the checkerboard task to further investigate the effects of levels and flatness. The results of a 2 x 3 (Group x Trial) MANOVA, with repeated measures on the last factor, did not support the hypothesis that prediction accuracy of young-old participants would be more accurate than that of old-old participants, $F(1,40) = 1.06$, $p = .31$. However, tests of flatness showed that the level of accuracy changed across trials, using the Hotelling's criterion, $F(2,39) = 5.10$, $p = .01$, $\eta^2 = .21$. The profiles did not deviate significantly from parallelism using the Wilks' criterion, $F(2,39) = 1.00$, $p = .38$, indicating that the changes across the Trial factor were similar for both groups. Planned univariate comparisons of within subjects effects, with a Bonferroni correction establishing alpha at .025, showed that the prediction accuracy of Trial 1 was significantly lower than

that for Trial 2, $F(2,40) = 5.96$, $p = .005$, $\eta^2 = .23$, as shown in Table 22. Comparison of Trial 2 and 3 failed to reveal a significant difference, $F(2,40) = .69$, $p = .51$.

A similar set of analyses was conducted to compare the prediction accuracy for checkerboard performance in the combined NI group and the PD group. A 2 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor and prediction accuracy on the checkerboard task as the dependent variables, supported the hypothesis that the NI group ($M = 3.18$, $SD = .47$) showed a higher level of prediction accuracy than the PD group ($M = 3.99$, $SD = 1.38$), $F(1,60) = 11.82$, $p = .001$, $\eta^2 = .16$. While both groups overestimated their ability on this task, the combined NI group average prediction was 1.06, in contrast to that of the PD at 1.33. When averaged over groups the profiles were found to deviate significantly from flatness using Hotelling's criterion, $F(2,59) = 13.79$, $p < .001$, $\eta^2 = .32$, and parallelism, Wilks' $F(2,59) = 5.09$, $p = .009$, $\eta^2 = .15$. Similar to the pattern of performance shown by the combined NI group across trials, a follow-up ANOVA with the PD group as the independent variable, and repeated trials of the checkerboard prediction accuracy found significant differences across trials, $F(2,38) = 10.49$, $p < .001$, $\eta^2 = .36$. As indicated in Table 22, accuracy was significantly higher for Trial 2 than for Trial 1, $F(1,19) = 11.65$, $p = .003$, $\eta^2 = .38$. Although prediction accuracy continued to improve on Trial 3 the difference was not found to be reliable, $F(1,19) = 2.06$, $p = .17$. An inspection of the means shown in Table 22 indicates that while the prediction accuracy of both groups showed improvement between Trials 1 and 2, the effect was more robust for the PD group as they had more room for improvement when compared to the combined NI group.

To further investigate the interaction of the group and trial effects on prediction accuracy of checkerboard performance, independent one-way ANOVAs were conducted for the combined NI and the PD groups on each Trial of checkerboard prediction accuracy. As expected from the pattern of means presented in Table 22, groups were found to differ significantly in the accuracy of their predictions on Trial 1, $F(2,59) = 5.70$, $p = .005$, $\eta^2 = .16$. Post hoc Tukey's pairwise comparisons, with the Bonferonni corrected alpha established at .017, found the NI young-old group to have a significantly higher level of accuracy than the PD group, HSD = .68, $p = .005$. Comparisons of the NI young-old and old-old groups (HSD = .17, $p = .70$) and the NI old-old and the PD (HSD = .51, $p = .05$) groups found their level of accuracy to be similar. Group differences in prediction accuracy on the checkerboard task were also significant on Trial 2, $F(2,59) = 3.37$, $p = .04$, although the effect size is smaller $\eta^2 = .10$. Post hoc Tukey's pairwise comparisons at this stringent level of alpha failed to reveal reliable differences between the groups (NI young-old and old-old: HSD = .02, $p = .98$; NI young-old and PD: HSD = .17, $p = .08$; NI old-old and PD: HSD = .18, $p = .06$). Prediction accuracy on the checkerboard task did not vary as a result of group membership on Trial 3, $F(2,59) = .53$, $p = .59$.

In summary, the accuracy of performance predictions for the checkerboard task was shown to be reliably higher for the NI groups, relative to the group of participants with PD. This difference in performance can be largely accounted for by the difference in prediction accuracy in Trial 1. However, improvements in accuracy were seen across trials, with all groups showing a very high level of accuracy for Trial 3.

The profiles of the NI young-old, old-old and the PD groups were compared on the accuracy of prediction on the handwriting task, with a 3 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor. The test of levels failed to reveal a significant difference in prediction accuracy between the groups, $\underline{F}(2,59) = 3.01$, $\underline{p} = .06$. The profiles did not deviate from parallelism, Wilks' $\underline{F}(4,116) = .80$, $\underline{p} = .53$, indicating that the pattern of performance across trials was similar for all groups. The test for flatness showed that the level of accuracy improved across trials, Hotelling's $\underline{F}(2,58) = 4.74$, $\underline{p} = .012$, $\eta^2 = .14$. When collasped across groups, prediciton accuracy was lower for Trial 1 ($\underline{M} = 1.25$, $\underline{SD} = .66$) than for Trial 2 ($\underline{M} = 1.02$, $\underline{SD} = .27$), and Trial 3 ($\underline{M} = .99$, $\underline{SD} = .17$). Planned univariate comparisons of within subjects effects failed to find the mean differences between the trials reliable with a Bonferroni correction establishing alpha at .025 (Trial 1 and Trial 2: $\underline{F}(3,59) = 2.78$, $\underline{p} = .05$; Trial 2 and Trial 3: $\underline{F}(3,59) = 1.10$, $\underline{p} = .36$), although without the correction the upgrade in prediction accuracy on Trial 2 relative to Trial 1 would reach significant. Group means for the accuracy of performance predictions on the handwriting task across trials are presented in Table 23.

Table 23

Mean Prediction Accuracy Scores for the Handwriting Task Across Trials

		Trial		
Group	n	1 (SD)	2 (SD)	3 (SD)
NI Young-Old	22	1.15 (.39)	.97 (.26)	.97 (.13)
NI Old-Old	20	1.18 (.44)	.95 (.21)	.97 (.17)
Parkinson's	20	1.44 (1.00)	1.15 (.31)	1.05 (.22)
Combined NI	42	1.16 (.41)	.96 (.23)	.97 (.15)

Note. Scores closer to 1 indicate a higher level of accuracy with scores < 1 indicating underestimates of performance and scores > 1 indicating an overestimate of performance.

Postdiction Accuracy. The relation between postdicted scores and actual performance scores was first analysed through Pearson product moment correlations for each of the three groups, NI young-old, old-old, and PD. As seen in Table 24, the pattern of correlations was similar across groups, generally remaining stable across trials.

Table 24

Postdiction and Performance Correlations Within Trials

Measure	Trial 1	Trial 2	Trial 3	Trial 4
		NI Young-Old (n = 22)		
Verbal Fluency	.68*	.67*	.62	.70*
CCST	.27	---	---	---
CVLT	.78*	.72*	.80*	.51
Checkerboard	.63	.82*	.76*	---
Handwriting	.81*	.96*	.93*	---

Table 24 continued

Measure	Trial 1	Trial 2	Trial 3	Trial 4
		NI Old-Old (n = 20)		
Verbal Fluency	.69*	.74*	.62	.70*
CCST	.53	---	---	---
CVLT	.76*	.76*	.83*	.68*
Checkerboard	.95*	.89*	.79*	---
Handwriting	.89*	.88*	.76*	---
		PD (n = 20)		
Verbal Fluency	.86*	.87*	.87*	.66
CCST	.60	---	---	---
CVLT	.54	.76*	.90*	.33
Checkerboard	.79*	.92*	.97*	---
Handwriting	.81*	.91*	.88*	---
		Combined NI (n = 42)		
Verbal Fluency	.66*	.70*	.61*	.71*
CCST	.54*	---	---	---
CVLT	.77*	.74*	.81*	.59*
Checkerboard	.82*	.87*	.81*	---
Handwriting	.85*	.94*	.89*	---

Note. CCST = California Card Sorting Test; CVLT = California Verbal Learning Test.

* $p \leq .001$.

Profile analyses were conducted to determine group differences in postdiction accuracy separately for executive tasks, memory tasks, and motor tasks. Specifically, for the purpose of these analyses, accuracy scores were derived by dividing the postdiction

score for each task by the actual performance score. Perfect accuracy of performance postdiction would result in an accuracy score of 1.0, whereas an accuracy score of greater or less than 1.0 would indicate an over or an underestimate of performance (McGlynn & Kaszniak, 1991). Separate one-way MANOVAs compared the profiles of the three groups on the derived postdiction accuracy measure, first on the verbal fluency tasks, second on the CCST, third on the CVLT, and fourth on the motor tasks. The dependent variable for the analysis of postdiction accuracy was phonemic verbal fluency was repeated across three trials. The semantic trial was examined separately. The dependent variable for memory tasks were the postdiction accuracy scores on the three trials of the CVLT. As the skills required for the recognition trial were thought to differ from those of free recall, the analysis for this trial was conducted separately. The accuracy scores for the motor measures, checkerboard and handwriting, were the dependent variables in the analyses of group differences in postdiction accuracy on motor tasks. It was expected that the NI young-old group would have greater accuracy across tasks than the NI old-old group of participants, and combined NI groups would have greater postdiction accuracy than the PD participants.

The 3 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor and the NI young-old, old-old, and the PD groups as the independent variables, comparing the postdiction accuracy scores for the phonemic verbal fluency task showed that the accuracy of the groups did not differ, $\underline{F}(2,59) = .37$, $\underline{p} = .69$, nor did they show significant deviation from parallelism, Wilks' $\underline{F}(4,116) = .18$, $\underline{p} = .95$. However, the test for flatness supported the hypothesis that postdiction accuracy would vary across trials, Hotelling's

$F(2,58) = 5.00$, $p = .01$, $\eta^2 = .15$. Univariate difference contrasts of the marginal means for the Trial factor, with a Bonferroni correction establishing alpha at .025, showed that while the postdiction accuracy did not vary between Trial 1($M = 1.05$, $SD = .29$) and Trial 2 ($M = 1.10$, $SD = .34$), $F(3,59) = 1.21$, $p = .31$, the accuracy level showed an increase between Trials 2 and 3 ($M = .99$, $SD = 32$), $F(3,59) = 3.54$, $p = .020$, $\eta^2 = .15$. Group means and standard deviations for each Trial are presented in Table 25.

Table 25

Mean Postdiction Accuracy Scores for the Verbal Fluency Tasks Across Trials

		Trial			
Group	n	1 (SD)	2 (SD)	3 (SD)	4 (SD)
NI Young-Old	22	1.08 (.37)	1.11 (.39)	1.03 (.42)	.89 (.27)
NI Old-Old	20	1.01 (.26)	1.05 (.35)	.95 (.31)	.86 (.21)
Parkinson's	20	1.05 (.21)	1.14 (.28)	.99 (.20)	.83 (.24)
Combined NI	42	1.04 (.32)	1.09 (.37)	.99 (.37)	.88 (.25)

Note. Scores closer to 1 indicate a higher level of accuracy with scores < 1 indicating underestimates of performance and scores > 1 indicating an overestimate of performance.

An ANOVA was conducted to compare group differences in postdiction accuracy on the semantic verbal fluency trial. Analysis failed to support the hypothesis that the groups differed on this measure, $F(2,59) = .30$, $p = .74$. As shown by the means in Table 25, all groups underestimated their level of performance on this task. An ANOVA comparing the group means of the postdiction accuracy of Trial 1 of the CCST also failed to find significant group differences, $F(2,57) = .03$, $p = .97$. Generally, participants

overestimated their performance on this measure. The mean estimate for the number of sorts produced by the NI young-old group was 1.46 (SD = .92), only slightly more accurate than the mean postdictive estimate for the NI old-old group of 1.52 (SD = .99). The mean for the PD group of 1.53 (SD = .75) was very close to that of the NI old-old group.

Profile analysis comparing the postdiction accuracy of the NI young-old, old-old, and PD groups on the three free recall trials of the CVLT were conducted with a 3 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor. The test of levels did not support the hypothesis of group differences, $F(2,58) = .98$, $p = .38$. However, postdiction accuracy was found to vary across trials with a test of flatness, Hotelling's $F(2,57) = 8.19$, $p = .001$, $\eta^2 = .22$. The profiles did not deviate from parallelism using Wilks' criterion, $F(4,114) = .64$, $p = .64$. Difference contrasts of the marginal means for the Trial factor in the C matrix found postdiction accuracy differed significantly between Trial 1 ($M = 1.17$, $SD = .52$) and Trial 2 ($M = .93$, $SD = .22$), with a Bonferroni correction establishing alpha at .025, $F(3,58) = 4.79$, $p = .005$, $\eta^2 = .20$. However, accuracy did not show significant change between Trials 2 and 3 ($M = 1.02$, $SD = .22$), $F(3,58) = 2.50$, $p = .069$. Inspection of the means in Table 26 shows an increase in accuracy between Trials 1 and 2 for all groups. Comparison of group differences in the postdiction accuracy on the CVLT recognition trial (Trial 4) with an ANOVA failed to show a significant group effect, $F(2,59) = .22$, $p = .81$. All groups underestimated their performance on Trial 4.

Table 26

Mean Postdiction Accuracy Scores for the California Verbal Learning Test Across Trials

		Trial			
Group	n	1 (SD)	2 (SD)	3 (SD)	4 (SD)
NI Young-Old	22	1.13 (.29)	.92 (.22)	1.01 (.22)	.78 (.20)
NI Old-Old	20	1.15 (.32)	.88 (.18)	1.02 (.26)	.70 (.24)
Parkinson's	19	1.25 (.81)	1.01 (.25)	1.02 (.19)	.67 (.22)

Note. Scores closer to 1 indicate a higher level of accuracy with scores < 1 indicating underestimates of performance and scores > 1 indicating an overestimate of performance.

Profile analysis comparing the postdiction accuracy of the NI young-old, old-old, and PD groups on the checkerboard task was conduced with a 3 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor. The results did not support the hypothesis that the groups differed in their ability to accurately estimate their performance on the checkerboard task, $F(2,59) = .24$, $p = .79$, and postdiction accuracy did not vary across trials, using a Hotelling's criterion, $F(2,58) = .79$, $p = .46$. The profiles were not found to deviate from parallelism, $F(4,116) = 1.68$, $p = .16$, indicating that the Group by Trial interaction was not significant. As seen in Table 27, the postdiction accuracy scores were similar across groups for the checkerboard task.

Table 27

Mean Postdiction Accuracy Scores for the Checkerboard Task Across Trials

		Trial		
Group	n	1 (SD)	2 (SD)	3 (SD)
NI Young-Old	22	.94 (.10)	1.01 (.08)	1.01 (.09)
NI Old-Old	20	.99 (.07)	1.01 (.08)	1.01 (.13)
Parkinson's	20	1.01 (.32)	.98 (.08)	1.00 (.05)

Note. Scores closer to 1 indicate a higher level of accuracy with scores < 1 indicating underestimates of performance and scores > 1 indicating an overestimate of performance.

Profile analysis comparing the NI young-old, old-old and PD groups on postdiction accuracy on the handwriting task was conducted with a 3 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor. The test of levels found that the postdiction scores varied reliably between the groups, $F(2,59) = 3.66$, $p = .03$, $\eta^2 = .11$. The NI young-old group ($M = 2.97$, $SD = .27$) had a very high level of accuracy with a slight tendency to underestimate their performance, averaging postdictions of .99 for each of the three trials. The estimates of the NI old-old group ($M = 2.88$, $SD = .24$) were less accurate, although they also showed a tendency to underestimate performance, averaging .96 for each of the trials. While the accuracy of the PD group was similar to that of the NI old-old group, ($M = 3.15$, $SD = .42$), the PD group showed a tendency to overestimate their performance on the handwriting task, averaging 1.05 for the three trials. The test for flatness showed that the slope of change between trials did not deviate significantly from zero, Hotelling's $F(2,58) = 1.36$, $p = .27$, and the profiles did not deviate from parallelism,

Wilks' $F(4,116) = 2.18$, $p = .08$. The group means and standard deviations for each trial are presented in Table 28.

Table 28

Mean Postdiction Accuracy Scores for the Handwriting Task across Trials

		Trial		
Group	n	1 (SD)	2 (SD)	3 (SD)
NI Young-Old	22	1.01 (.19)	.97 (.10)	.99 (.09)
NI Old-Old	20	.96 (.13)	.97 (.10)	.95 (.13)
Parkinson's	20	1.02 (.20)	1.10 (.15)	1.03 (.17)
Combined NI	42	.99 (.16)	.97 (.10)	.97 (.11)

Note. Scores closer to 1 indicate a higher level of accuracy with scores < 1 indicating underestimates of performance and scores > 1 indicating an overestimate of performance.

The profiles of the NI young-old and old-old were compared on postdiction accuracy for the handwriting task to further investigate the Group effects. The results of a 2 x 3 (Group x Trial) MANOVA, with repeated measures on the Trial factor failed to show a significant effect for Group, $F(1,40) = 1.26$, $p = .27$. As with the previous omnibus analysis, the effect for levels, Hotelling's $F(2,39) = .12$, $p = .89$, and parallelism, Wilks' $F(2,39) = 1.38$, $p = .26$, were not significant.

A similar analysis with the combined NI group and the PD group as the independent variable was conducted. Postdiction accuracy for performance on the handwriting task was reliably different for these groups, $F(1,60) = 6.53$, $p = .01$, although the effect size was small $\eta^2 = .10$. The postdiction accuracy of the combined NI group (M

= 2.93, SD = .26) was greater than that of the PD group (M = 3.15, SD = .42) across the three trials. Again, the test for flatness was not significant, Hotelling's F(2,59) = 2.70, p = .08. However, the profiles were found to deviate from parallelism, Wilks' F(2,59) = 3.41, p = .04, η^2 = .10. To further investigate the Group by Trial interaction independent ANOVAs were conducted for each Trial of handwriting postdiction accuracy, with the combined NI and the PD groups as the independent variable. The Bonferroni corrected alpha was established at .017. Postdiction accuracy scores were not found to differ significantly according to group membership on Trial 1, F(1,60) = .61, p = .44. However, the differences between groups on Trial 2 were found to be reliably different, F(1,60) = 15.87, p< .001, η^2 = .21. As shown in Table 28, the combined NI group underestimated performance on the handwriting task, while the PD group had overestimates on Trial 2. On Trial 3, postdiction accuracy scores were not found to be related to group membership, F(1,60) = 2.29, p = .14. In summary, postdiction accuracy on the handwriting task was found to be related to group membership, largely due to differences in accuracy on Trial 2.

Analysis of the relation between prediction and postdiction accuracy was assessed through Pearson product moment correlational analysis. The prediction accuracy score for each trial, within each measure, was correlated with the corresponding score for the postdiction task for each group. It was expected that the magnitude of the correlations would increase with each trial, with the correlation between Trial 3 predictions and postdictions showing the greatest magnitude. Bonferroni corrections established the alpha level at .001 to reduce the probability of Type I error. As shown in Table 29, the general

pattern of correlations shows a greater magnitude for the relation between prediction and postdiction accuracy scores for executive function and memory tasks than for the motor tasks. This pattern is similar across groups, although the correlations for the PD group appear to be lower than those for the NI groups.

Table 29

Accuracy Score Prediction and Postdiction Correlations

Measure	n	Trial 1	Trial 2	Trial 3	Trial 4
			NI Young-Old		
Verbal Fluency	22	.81*	.86*	.71*	.67*
CCST	22	.95*	---	---	---
CVLT	22	.56	.64*	.70*	.58
Checkerboard	22	-.04	.69*	.42	---
Handwriting	22	.15	-.13	.71*	---
			NI Old-Old		
Verbal Fluency	20	.62	.82*	.83*	.65
CCST	19	.86*	---	---	---
CVLT	20	.08	.66	.82*	.54
Checkerboard	20	-.05	.32	.07	---
Handwriting	20	-.40	.25	.19	---
			PD		
Verbal Fluency	20	.25	.33	.49	.83*
CCST	19	.95*	---	---	---
CVLT	19	.52	.74*	.03	.46
Checkerboard	20	.39	.20	.29	---
Handwriting	20	.01	.46	.66	---

Table 29 continued

Measure	n	Trial 1	Trial 2	Trial 3	Trial 4
			Combined NI		
Verbal Fluency	42	.72*	81*	75*	65*
CCST	41	.72*	---	---	---
CVLT	42	.14	.63*	.75*	.55*
Checkerboard	42	.02	.52*	.23	---
Handwriting	42	-.07	.03	.38	---

Note. CCST = California Card Sorting Test; CVLT = California Verbal Learning Test.

* $p \leq .001$.

Questionnaire responses. To test the magnitude of the relation between the metacognitive questionnaires and on-line metacognitive functions, Pearson product moment correlations were conducted with the actual prediction and postdiction scores for each task and the sum of the Metamemory and the Metamovement questionnaires, separately. Correlations of the questionnaire data from each participant group and the actual prediction scores for each task are presented in Table 30. The alpha level was established at .001 to reduce the probability of Type I error. As predictions were only obtained on the first trial of the CCST they were not included in the table. Correlations of the CCST prediction scores and questionnaire responses ranged from $r = -.02$ for the NI old-old group on the Metamemory questionnaire, to $r = -.32$ for the PD group on the Metamemory questionnaire. While these correlations are small, generally they are in the

expected direction, as higher levels of perceived performance are reflected in lower scores on the questionnaires and higher prediction scores.

Table 30

Correlations between Questionnaire Responses and Prediction Scores across Tasks

Trial	Verbal Fluency	CVLT	Checkerboard	Handwriting
		NI Young-Old Metamemory Questionnaire		
1	.36	.10	-.11	-.03
2	.19	.16	.09	-.21
3	.15	.17	-.05	.11
4	.06	.27	---	---
		NI Young-Old Metamovement Questionnaire		
1	-.15	-.13	-.32	-.22
2	.01	-.21	-.06	-.15
3	.00	.03	-.23	-.29
4	-.04	-.05	---	---
		NI Old-Old Metamemory Questionnaire		
1	.04	-.47	.31	-.31
2	.07	-.42	-.13	.06
3	.12	-.71*	-.30	-.24
4	.04	-.57	---	---
		NI Old-Old Metamovement Questionnaire		
1	-.17	-.05	-.13	.24
2	.11	.13	-.07	-.15
3	.17	-.11	-.27	-.24
4	.10	.35	---	---

Table 30 continued

Trial	Verbal Fluency	CVLT	Checkerboard	Handwriting
		PD Metamemory Questionnaire		
1	-.12	-.08[a]	.32	.37
2	-.19	-.21	-.25	-.32
3	-.05	-.21	-.19	-.25
4	-.03	-.29	---	---
		PD Metamovement Questionnaire		
1	.06	.44[a]	-.13	-.13
2	.12	.24	-.56	-.30
3	.20	-.20	-.62	-.48
4	-.01	-.28	---	---
		Combined NI Metamemory Questionnaire		
1	.20	-.17	.05	-.18
2	.10	-.12	-.10	-.21
3	.04	-.18	-.25	-.10
4	.05	-.17	---	---
		Combined NI Metamovement Questionnaire		
1	-.04	-.17	-.23	-.30
2	-.04	.08	-.22	-.28
3	.01	-.06	-.39	-.35
4	.01	-.08	---	---

Note. NI young-old $n = 22$; NI Old-Old $n = 20$; NI Combined $n = 42$; PD $n = 20$.

[a] Number of participants was reduced by one for this measure.

*$p \leq .001$.

As seen in Table 30, the magnitude of the correlations between the CVLT predictions and the Metamemory questionnaire for the NI young-old were small, suggesting that there is little relation between these two types of metamemory measures for this group. The correlations of the Metamovement questionnaire with predictions of movement tasks were generally larger and in the expected direction, indicating that people who perceived a higher level of difficulty on daily tasks of motor function also predicted lower levels of performance on the checkerboard and handwriting tasks. It is somewhat of an enigma that while the magnitude of correlations for the verbal fluency measure was the highest with the Metamemory questionnaire for the NI young-old group, the direction of the correlations was positive. The NI old-old group showed correlations of the highest magnitude between the Metamemory questionnaire and the CVLT, with lower predictions relatd to higher levels perceived difficulty with common memory tasks. The correlations of the motor tasks were similar for both questionnaires in the NI old-old group. In general, the magnitude of the correlations for the PD group were higher than for the other two groups, particularly for the motor tasks. While the correlation between the Metamemory questionnaire and the CVLT were very small on the first trial for the PD group, the correlation between the Metamovement questionnaire and the CVLT was positive, and in the moderate range. This suggests that people who perceived greater difficulty with motor problems were more apt to endorse few problems with memory function. The wider range of scores for the PD group offers a possible explanation for these higher correlations.

A similar set of correlations were calculated to assess the relation between questionnaire data and actual postdiction scores for each participant group. The correlations are shown in Table 31, with the exception of the correlations between questionnaire data and Trial 1 postdiction scores for the CCST, which ranged from $\underline{r} = -.00$ for the combined NI group on the Metamemory questionnaire, to $\underline{r} = -.41$ for the combined NI group on the Metamovement questionnaire. The small size of these correlations supports the contention that questionnaires on metacognition and performance prediction and postdictions are two distinct constructs of metacognition.

Table 31

Correlations between Questionnaire Responses and Postdiction Scores across Tasks

Trial	Verbal Fluency	CVLT	Checkerboard	Handwriting
	NI Young-Old Metamemory Questionnaire			
1	.23	.30	.09	-.13
2	.25	.28	-.03	.23
3	.22	.31	-.15	.20
4	.18	.21	---	---
	NI Young-Old Metamovement Questionnaire			
1	-.11	-.17	-.08	-.22
2	-.25	-.18	-.10	-.17
3	-.18	.15	.07	-.29
4	-.07	-.12	---	---

Table 31 continued

Trial	Verbal Fluency	CVLT	Checkerboard	Handwriting
		NI Old-Old Metamemory Questionnaire		
1	.16	-.40	-.13	.39
2	.02	-.50	-.08	-.11
3	-.08	-.55	.01	-.17
4	-.08	-.17	---	---
		NI Old-Old Metamovement Questionnaire		
1	.02	-.11	-.26	-.05
2	-.01	-.15	-.38	-.20
3	-.04	.00	-.19	-.25
4	.04	.22	---	---
		PD Metamemory Questionnaire		
1	-.03	-.19[a]	-.09	-.36
2	-.04	-.48	.05	-.23
3	.13	-.10	-.01	-.22
4	-.27	-.05	---	---
		PD Metamovement Questionnaire		
1	.28	.35[a]	-.39	-.35
2	.19	-.35	-.68*	-.39
3	.35	-.22	-.64	-.41
4	-.06	-.29	---	---

Table 31 continued

Trial	Verbal Fluency	CVLT	Checkerboard	Handwriting
		Combined NI Metamemory Questionnaire		
1	.16	-.25	-.10	-.03
2	.12	-.10	-.14	.01
3	.07	-.08	-.16	-.04
4	.05	.05	---	---
		Combined NI Metamovement Questionnaire		
1	-.12	-.20	-.28	-.28
2	-.18	-.20	-.37	-.30
3	-.18	.02	-.22	-.38
4	-.10	.04	---	---

Note. NI young-old n = 22; NI Old-Old n = 20; NI Combined n = 42; PD n = 20.

[a] Number of participants for this measure was reduced by one.

* $p \leq .001$.

The pattern of correlations between the Metamemory questionnaire and the CVLT postdiction scores showed less variability than the correlations with the prediction scores. The postdiction correlations were consistently negative for the NI old-old and the PD groups, as expected. However, the positive correlations for the NI young-old group across trials is curious. As reported levels of daily memory function increased, producing low scores on the Metamemory questionnaire, this group was apparently less confident in their performance on this list-learning task, resulting in lower postdiction scores. Correlations between the Metamovement questionnaire and the movement measures of the

checkerboard and handwriting tasks were generally low for the NI groups, although they were in the moderate range for the PD group and were higher than the correlations with the prediction scores. This pattern of correlations with the two questionnaires suggests that while the CVLT and the postdiction estimates of performance on the CVLT show a greater degree of similarity for the NI groups, the reports of daily motor function and estimates of performance on motor tasks are more similar for the PD group. One possible explanation for this pattern is that the NI groups preceive a greater risk of failure in memory performance, while motor performance is more salient for the PD group.

Correlations of the metacognitive questionnaires with prediction and postdiction performance accuracy scores were of a similar magnitude to those of the actual prediction and postdiction scores presented in Table 30 and 31.

To examine the significance of group differences between NI young-old, old-old, and PD participant's questionnaire responses, a one-way MANOVA was conducted with the sum of the responses from the Metamemory and the Metamovement questionnaires as the dependent variables. Results showed group responses differed on the two questionnaires, Wilks' $F(4,114) = 13.73$. $p < .001$, $\eta^2 = .50$. Follow-up ANOVAs conducted for each of the questionnaires independently found that group responses varied only on the Metamovement questionnaire, $F(2,59) = 27.48$, $p < .001$, $\eta^2 = .48$, while the responses were similar on the Metamemory questionnaire, $F(2,59) = 2.16$, $p = .12$. Post hoc tests comparing group responses, with a Bonferroni correction establishing alpha at .017 found a significant difference in group responses between the NI young-old group and the PD group, Tukey's $HSD = 20.700$, $p < .001$, and the NI old-old group and the PD

group, Tukey's HSD = 13.30, $p < .001$. Contrasts between the NI young-old and old-old groups were not significant, Tukey's HSD = 7.40, $p = .03$, suggesting that group differences in reponses on the metamovement questionnaire were largely due to the PD group reporting greater difficulty with daily tasks than the NI groups, as shown in Table 32.

Table 32

Group Means on Metacognitive Questionnaires

		Questionnaires	
Group	n	Memory (SD)	Movement* (SD)
NI Young-Old	22	46.96 (11.75)	29.00 (7.89)
NI Old-Old	20	51.40 (11.33)	36.40 (7.90)
Parkinson's Disease	20	52.60 (7.47)	49.70 (11.27)
Combined NI	42	49.07 (11.63)	32.52 (8.65)

Note. * Group differences significant at $p < .001$.

Executive Functioning and Task Performance

The hypothesis that scores on measures of executive functioning are related to performance on tasks of memory and movement was examined using multivariate analysis of covariance (MANCOVA), with the variance associated with executive tasks partialled out of the dependent variables (Bondi et al., 1993). Support for the hypothesis would be indicated if group effects were no longer significant once the variance associated with the executive tasks was removed from the performance measures. As the numerical scales of the conceptual groups of executive, memory, and motor tasks differ, the data was

transformed to standardized z scores with the sign reversed where needed so that better performance was reflected by a positive z score. Composite scores were then created for tasks with multiple variables or trials. For example, the CCST yields three variables of interest, percentage of sorting accuracy, total score, and total perseverations. Measures with several variables were transformed to z scores and averaged together to provide a single CCST variable: [z(percentage sorting accuracy) + z(total score) + z(total perseverations)(-1)]/3. Tasks with multiple trials were summed together and transformed to standardized scores to obtain a single variable. In the first analyses, three variables representing the executive tasks, composite scores for verbal fluency, CCST, and CVLT variables of total intrusions, total perseverations, and ordering, were submitted to a 3 x 3 (Group x Task) MANOVA to examine group differences, with the NI young-old, the old-old, and the PD groups as the independent variable. As expected, the combined executive tasks were significantly related to group membership, Wilks' $F(6,108) = 4.69$, $p < .001$, $\eta^2 = .37$. Follow-up ANOVAs with each dependent variable found the groups to differ only on the verbal fluency and the CCST measures, $F(2,56) = 8.03$, $p = .001$, $\eta^2 = .22$; $F(2,56) = 4.49$, $p = .016$, $\eta^2 = .14$, respectively. Group performance on the CVLT executive tasks did not differ, $F(2,56) = 1.64$, $p = .20$. As such, the CVLT measure was not included in the subsequent analyses.

In the second analysis a 3 x 3 (Group x Task) MANCOVA was performed on the composite standardized scores for the three dependent variables: CVLT memory, checkerboard, and handwriting. Adjustment was made for two covariates: verbal fluency and CCST. The independent variable was group membership. Using Wilks' criterion, the

combined dependent variables were significantly related to group membership, $F(6,110) = 5.29$, $p < .001$, $\eta^2 = .40$, after the executive tasks were statistically covaried. Overall, the variance associated with the executive measures did not have a significant impact on the combined dependent variables. To investigate the power of the covariates to adjust the dependent variables one-way analysis of covariance (ANCOVAs) were conducted individually for each dependent variable. Results, with a Bonferroni adjusted alpha set at .016, found that scores on the motor tasks remained significant after the variance associated with the executive tasks was removed, checkerboard: $F(2,57) = 15.14$, $p < .001$, $\eta^2 = .35$; handwriting: $F(2,57) = 7.20$, $p = .002$, $\eta^2 = .20$, suggesting that performance on these tasks was largely independent of executive funciton. However, once variance associated with the executive tasks was removed from the CVLT scores performance on this task was no longer significantly related to group membership, $F(2,57) = 2.50$, $p = .09$.

An additional MANCOVA was conducted with the averaged CVLT score as the covariate for the dependent variables of the verbal fluency and the CCST scores as measures of executive functioning. Group membership, as the independent variable, remained significant, Wilks' $F(4,114) = 3.28$, $p = .014$, $\eta^2 = .20$. While performance on the CVLT was influenced by performance on the executive tasks, performance on the CVLT did not have a significant effect on performance on verbal fluency and the CCST.

Executive Functioning and Metacognition

The hypothesis that scores on measures of executive functioning are related to prediction accuracy was examined using a MANCOVA, to adjust the dependent variables

for the variance associated with executive tasks. Support for the hypothesis would be indicated if group effects were no longer significant once the variance associated with the executive tasks was removed from the accuracy score. As in the previous section, standardized composite scores were used to equate the metric across tasks. Analyses reported earlier showed that prediction accuracy was not related to group membership on the verbal fluency or handwriting tasks, therefore these scores were not included in the analyses. A 2 x 3 (Task x Group) MANCOVA was conducted, with the prediction accuracy represented by the standardized composite sum of the three trials on the CVLT and the standardized composite sum of the three trials on the checkerboard task as the dependent variables. The standardized composite verbal fluency score and the standardized composite CCST score were the covariates. Group membership, as the independent variable, remained significant once the variance associated with the executive tasks was removed, Wilks' $F(4,110) = 3.09$, $p = .02$, $\eta^2 = .19$. As tests of memory and motor performance assess conceptually different behaviours and there was concern that the variance associated with the executive tasks may play a more important role in one type of task than in the other, independent analyses of covariance (ANCOVAs) were conducted for each of the standardized composite variables, the CVLT score and the checkerboard score, as the dependent varables. Group membership was once again the independent variable, and adjustments were made for the executive scores of verbal fluency and CCST. Results, with a Bonferroni adjusted alpha set at .025, showed group membership was no longer significant for prediction accuracy on the CVLT once the variance associated with the executive tasks was removed, $F(2,56) = 1.57$, $p = .22$. In

contrast, group membership showed little change on the checkerboard prediction accuracy when the executive task variance was partialled out, $F(2,57) = 6.34$, $p = .003$, $\eta^2 = .18$.

A 2 x 3 (Task x Group) MANCOVA was also conducted with the standardized composite scores of the verbal fluency and the CCST tasks as the dependent variables, and group membership as the independent variable. Adjustments were made for the prediction accuracy standardized composite score on the CVLT. The combined executive task measures remained significantly related to group membership when the variance associated with the CVLT prediction accuracy was covaried, Wilks' $F(4,112) = 4.05$, $p = .004$, $\eta^2 = .24$. These results suggest that executive function, as measured by verbal fluency and the CCST in this study, has a differential impact on the prediction accuracy on word-list memory task, while playing a smaller role in the accuracy of predictions on a motor task involving hand and arm movements.

Postdiction accuracy was significantly associated with group membership only on the handwriting task, as reported earlier. An ANCOVA was performed with the standardized composite postdiction accuracy scores of the handwriting task as the dependent variable and group membership as the independent variable. Adjusting for the variance associated with the executive tasks of verbal fluency and the CCST, group membership was no longer significant, $F(2,57) = 2.37$, $p = .103$. A follow-up 2 x 3 (Task x Group) MANCOVA was conducted with the executive tasks as the dependent variables and group membership as the independent variable. The handwriting postdiction accuracy score was the covariate. Group differences on the verbal fluency and the CCST remained significant once the variance associated with the handwriting was removed, Wilks'

$F(4,114) = 5.15$, $p = .001$, $\eta^2 = .28$. In summary, postdiction accuracy on the handwriting task was significantly influenced by the variance associated with the executive tasks. However, removing variance associated with postdiction accuracy on the handwriting task from the verbal fluency task and the CCST did not reduce the significance of group membership.

Chapter V

Discussion

This study was designed to inform theoretical and clinical understanding of the relation between executive function and metacognition in late adulthood, and to examine the effects of PD on these aspects of the executive control system. The sample included two groups of neurologically intact (NI) elderly adults and a group of participants with Parkinson's Disease (PD). All participants were over the age of 55 years.

Psychometric Results

As the Metamemory and Metamovement questionnaires used in this study were either composites of existing scales or new measures it was necessary to examine the internal consistency of the scales. The internal consistency of the metamemory questionnaire, which was composed of the Capacity subscale from the MIA and the Frequency of Forgetting item from the MFQ, was consistent with the findings of Dixon, Hultsch, and Hertzog (1988) for the MIA Capacity scale alone, for the NI participants. While the internal consistency for the PD group remained in the moderate range, it was somewhat lower than the results reported in the Dixon study. These results further support the research conducted by Hertzog, Hultsch, and Dixon (1989) showing good convergent validity between the MIA and the MFQ metamemory questionnaires. The Metamovement questionnaire, designed to assess awareness of motor function, showed good internal consistency across the groups, suggesting that the items were tapping a similar construct.

Contrary to expectations, correlational analyses conducted to assess the relation between motor and memory factors of metacognition found small to medium size correlations between the two questionnaires. The hypothesis that the questionnaires would share a substantial overlap in variance was based on the idea that awareness and knowledge of general functioning, acquired through performance monitoring, would form an underlying construct of metacognition as measured by the questionnaires. While these results indicate a small degree of common variance, responses based on the ability to monitor and report functioning were primarily domain specific. As such, the ability to monitor one domain could be relatively intact while the same ability could be impaired in another domain of functioning. As memory and motor function are very different systems (Stuss, 1991b), it is not surprising to find that the measures of systemic awareness within each system share only a small proportion of variance. The importance of self-efficacy in response patterns on metamemory questionnaires (Hertzog, Dixon, & Hultsch, 1990a; Hertzog, Saylor, Fleece, & Dixon, 1994) suggests a possible basis for the general construct of metacognition that would be worthy of further investigation. It may be that the self-efficacy of motor function has little or no relation to the self-efficacy of memory abilities. In addition, the impact of limited processing resources may also be a factor in these results, particularly for the study participants with PD, as the focus of resources could be expected to be directed to monitoring motor function, consequently reducing available resources for monitoring memory function.

Group Differences on Tests of Executive Function

In general, the hypothesis that NI old-old participants would perform more poorly on neuropsychological tests of executive functioning than NI young-old participants received limited support. While the performances of the NI groups were similar on most measures of executive functioning, differences were found in the number of correct sorts produced on the CCST. One of the unique aspects of this measure is that it taps the ability to generate novel concepts, as opposed to the well-learned concepts required for the tasks of verbal fluency. Consistently, the research has found age-related deficits in the ability to generate and implement guiding principles for task completion (Boone et al., 1990; Cronin-Golomb, 1990; Daigneault, Braun, & Lesser, 1992), the primary component tested with the CCST. On a previous study requiring research participants between the ages of 18 and 79 years to freely generate concepts on a task similar to the CCST, Levine, Stuss, and Milberg (1995) found that age-related differences in self-initiation of categorical sorts was reduced as the level of structured support increased. As Levine, Stuss, and Milberg point out, task self-initiation places heavy demands on processing resources, which are therefore more likely to reflect age-related decline earlier than less demanding tasks (Craik, 1986). These results serve to highlight the proposal that age-related declines in executive functioning first appear in tasks that require a high level of cognitive processing, particularly in people with high levels of education. In daily life, the relevance of declines in the ability to generate novel concepts under time-limited conditions, is likely to surface primarily in demanding, problem-solving situations. The increasingly large fund of experience commonly compiled with advancing age, in

conjunction with normal age-related lifestyle changes could function as compensatory mechanisms to keep environmental demands in line with the capabilities of this declining aspect of the executive control system, minimizing the impact of these changes (Bäckman & Dixon, 1992). For example, shifting lifestyle emphasis from cognitively demanding tasks which require the rapid generation of complex novel solutions frequently occurs as people leave the work force, thereby bringing expectations in line with these modest declines in executive functioning.

The implications of the failure to find age-related declines in this sample are necessarily restricted by two factors. The first is the narrow age difference, of little more than 12 years, between the groups. A difference of this magnitude may not be sufficient to reveal the hypothesized age-related effects in other areas of the executive control system. Second, the probability that the high level of education in this sample may be related to greater reserve of cognitive capacity must also be considered. This process would be similar to that found in clinical samples where pathological organic changes are typically more advanced in highly educated individuals before cognitive impairment becomes evident (Teng, Chui, Schneider, & Metzger, 1987).

This study also examined the impact of PD, typically resulting in pathological degeneration of the connections between the frontal lobes and subcortical areas of the brain, on executive functioning. The statistical analysis showed that the participants with PD were impaired on several tasks of executive functioning relative to the NI groups. Specifically, the PD group performed more poorly on the number of correct sorts generated on the CCST, as well as on the phonemic and the semantic conditions of verbal

fluency, tasks related to concept formation and initiation. In this sample, the age of the PD group was similar to that of the NI young-old participants. However, their ability to generate novel concepts, as measured by the CCST was found to be lower than that of the NI young-old group and similar to the NI old-old group. Performance on the verbal fluency tasks was lower than that of the combined NI group. Deficits in executive functioning, in excess of age-related change, could further restrict the range of activities available to persons with PD. As the ability to draw on even well-learned information declines, successful attempts for rehabilitation to approximate a normal lifestyle would have to include clear and explicit definitions of concrete goals and the necessary organizational framework to produce the desired outcome.

Group Differences on Tasks of Memory

Despite the literature showing age-related declines in memory function, the NI young-old and old-old participants in this study had a similar level of performance on free recall and recognition list-learning tasks. However, the expected learning curve was evident for both groups, with an significant increase in the number of words recalled on the second immediate recall trial, and much of this information retained following delay. As shown in the normative studies for the CVLT, participants identified a significantly greater number of list-words in the recognition trial, than in the preceding free-recall trial (Delis, Kramer, Kaplan, & Ober, 1987). Theoretically, changes in memory function have been linked to age-related changes in the executive abilities of planning, organization, and temporal ordering. As the young-old and the old-old groups in this study showed a similar level of performance on many aspects of executive function, including the use of recall

strategies and temporal ordering, failure to find group differences on memory tasks was not surprising.

The differences between the NI participants and those with PD on tests of memory recall and recognition also mirrored the findings on tests of executive function. As discussed above, the PD participants had greater difficulty with tasks drawing on the ability to generate novel concepts, both measuring reactive flexibility, as in the case of the CCST, and spontaneous flexibilty, as with the verbal fluency tasks. These difficulties offer an explanation for the lower performance of the PD group on the free recall of list-words relative to the NI group. While the PD group also recognized fewer list-words on the recognition trial than the NI groups, this difference failed to reach significance under the stringent alpha used in the post hoc analyses. Nevertheless, these results suggest that the PD group had a greater difficulty with word retrieval than the NI groups. This pattern of findings, showing a close association between scores on tasks of executive function and verbal memory, provides additional support for the contention that executive function plays a mediating role in memory performance made by Troyer, Graves, and Cullum (1994).

Group Differences on Motor Tasks

As expected, comparison of the NI young-old and old-old participants showed significant differences in their performance of motor tasks, with the younger group achieving more target movements than the older group. Both groups showed a learning effect, placing more checkers and drawing more backward *h*s on the second trial than on the first. While this performance level was maintained for the third trial of the

checkerboard task, performance on the handwriting task showed a trend toward continued improvement, especially for the older group.

Due to the difference in the performance of the NI young-old and old-old groups on the checkerboard task, the performance of each of these groups was independently compared to that of the PD participants. As expected, both NI groups showed faster movements than the PD group, with the largest effect size found when comparing the PD group to the NI young-old group, despite age similarities between these two groups. Similar to the learning effect seen with the NI groups, the PD participants also placed more checkers on the second trial than the first and maintained this level of performance for the third trial.

The results from the comparisons of the group with PD and the NI groups on the handwriting task were more complex than those found on the checkerboard task, possibly due to the greater demands of fine motor control required for handwriting tasks. Overall, both the NI young-old and the old-old participants generated more backward *h*s than the PD participants, with a moderate effect size in the NI young-old comparison and a small effect size for the old-old comparison. While the performance trend over repeated trials was similar for all groups, showing a general increase across three trials, a comparison of the performance of the NI young-old and the PD groups revealed a greater increase for the NI young-old participants over the first two trials relative to the PD participants who showed little motor learning over the three trials. In contrast, the pattern of performance for the PD and the NI old-old groups was found to be similar over repeated trials.

These results suggest that the motor movements required in the checkerboard and handwriting tasks are significantly related to age, as well as to the disease process of PD. In addition to the motor component, the checkerboard and handwriting tasks draw on the ability to plan and initiate the required motor responses. Overall, the participants in this study showed an improvement in executing target movement in Trial 2 compared with Trial 1, possibly resulting from a greater familiarity with the task and a consequent reduction in planning time. These results support previous research which shows age-related declines on executive tasks that incorporate a motor component, such as task demands drawing on planning, movement selection, and initiation (Stuss et al., 1984; Kolb & Wishaw, 1995). The current study found differences in performance on tasks of executive functioning related to age (CCST) and to diagnosis (verbal fluency). The increased sensitivity of motor tasks to performance differences related to age and to PD may result from the cumulative effects of changes in aspects of executive function and motor slowing.

Group Differences on Tasks of Metacognition

Performance Predictions. Independent of prediction accuracy, differences in the perception of performance was examined through actual prediction scores. Overall, perceptions showed age-related variability on only two of the five tasks incorporating performance predictions. Specifically, the NI young-old predicted a higher level of performance on the CCST and the handwriting task, while the NI young-old and old-old groups predicted a similar level of performance on the tasks of verbal fluency, the CVLT, and the checkerboard task. This pattern of results is similar to that of the actual

performance scores of these two groups on the tasks of executive function and memory. However, while the performance scores on the checkerboard task showed an effect for age, this was not reflected in the predictions. As this is a simple gross motor task, it is possible that gradual, age-related change escaped notice.

A comparison of the participants with PD to those in the NI groups, to investigate the effect of diagnosis, generally showed that the PD participants expected to perform at a similar level to the NI groups. Exceptions, showing group effects for diagnosis, were only evident on the CVLT which showed a small group effect, and on the handwriting task where the difference in predictions were limited to comparison with the young-old NI group. Perhaps most surprisingly, the performance prediction on the checkerboard task was similar for all groups, with the PD group predicting a slightly higher mean level of performance on the first trial than the NI groups. These results are a departure from the actual scores, indicating an effect for diagnosis on most tasks, as discussed earlier.

Changes in predictions across trials on all tasks, with the exception of verbal fluency, suggests that participants used knowledge of the task to inform predictions. Predictions on the CVLT highlight this point, as participants expected to recognize more list-words on the recognition trial than they expected to recall in the preceding delayed free-recall trial. This alteration of expectations can be explained as a general awareness of the utility of a recognition format in facilitating recall. However, it must also be considered that given the study design, order effects cannot be dissociated from memory condition. Therefore, changes in prediction solely due to order effects cannot be ruled out. However, the insignificant amount of change between the second learning trial and

the delayed recall trial, and the size of the effect between the delayed recall trial and the recognition trial ($\eta^2 = .54$) supports the contention that this difference is not due solely to the effects of order on this measure. Examining the mean predictions on the motor tasks (checkerboard and handwriting) shows a trend toward decline in predictions for Trial 2 relative to Trial 1. Hertzog, Saylor, Fleece, and Dixon (1994) also found that participants altered predictions in response to experience with the task, offering a possible explanation for these changes.

As the ability to monitor performance and to use the experience gained over repeated trials to change task predictions was found to be insensitive to age and diagnosis, the next task was to examine group differences in the perception of daily functional abilities through the use of the Metamemory and Metamovement questionnaires. The Metamemory questionnaire did not discriminate between the groups. On basic tasks of daily memory function, the PD group reported slightly more memory problems than the NI old-old and the NI young-old groups, and the NI young-old group reported the fewest problems, as expected. However, these differences were not statistically significant. Responses on the Metamovement questionnaire were higher for the PD group who reported greater difficulty with daily motor tasks, such as dressing and eating, than the NI groups.

Performance Postdictions. Performance postdiction scores were also used as a measure of metacognition, drawing on the ability of the participants to monitor their performance, or to analyse the effects of their planned action, an important aspect of effective plan implementation. Performance postdictions of the NI young-old and old-old

groups showed more variability than the performance predictions. The NI groups made similar appraisals of their performance on the verbal fluency task, and the CVLT. That is, the perceptions of performance on these two tasks was not influenced by age. However, the postdictions of the NI young-old group were higher than those of the NI old-old group on the CCST, and for both the checkerboard and the handwriting tasks.

In general, the participants in this study with PD were less confident in their test-taking behaviour than the NI groups. On measures of executive functioning, the effects of diagnosis were only significant for verbal fluency, with the NI groups reporting the perception of higher levels of performance than the PD group. Given that the PD group predicted they would perform at a level similar to that of the NI groups on both executive tasks, these results suggest an incongruence between behavioural expectations as measured by the prediction scores, and the perception of outcome as measured by the postdictions scores. The effect for diagnosis, with the PD group reporting lower levels of performance than the NI groups, was repeated for the CVLT memory tests and the checkerboard task. Significant differences in postdiction were also found between the reports of the NI young-old and the PD groups on the handwriting task, with the PD group reporting a level of performance similar to the NI old-old group.

Changes in postdictions across trials for each task were assessed to determine the degree to which participants altered their reports in response to increased task experience. Postdiction estimates on verbal fluency showed little change, despite differences in the number of words generated in the phonemic and the semantic conditions. Postdictions for the memory task were similar to the performance predictions, with PD participants

reporting a similar pattern of performance to the combined NI group, albeit at a lower level. Generally, the participants reported that they had recalled more words on the second learning trial (Trial 2) than on the first (Trial 1), and they had recognized more of the list-words on the forced-choice format (Trial 4) than they were able to recall without memory aids on the delay trial (Trial 3). The contrast between the second learning trial and the delay trial was not significant, although the norms for the CVLT indicate that most people recall fewer words following a delay than immediately after list presentation. Checkerboard postdictions generally improved across trials, showing a significant increase between Trials 1 and 2 for the NI groups. The PD group reported little change in their performance over the three trials. Similarly, all groups reported improving performance on the handwriting task across trials, with the greatest degree of change occurring between Trials 1 and 2. These results suggest that participants felt that the first trial helped them improve their level of performance, but they gained little benefit from the second trial.

To this point, the discussion has focused on task performance and the estimates, both predictions and postdictions of that performance. The questions to be discussed in the following sections will focus on the relation between prediction and postdiction scores, and their relation to actual performance examined through accuracy measures.

Relation between Performance Prediction and Postdiction Scores. The relation between performance prediction and postdiction scores was assessed through Pearson product moment correlations. It was expected the intra-trial correlations would increase in magnitude across trials for each task, with the highest correlations between prediction

and postdiction scores occurring on the final trial. The results showed that the pattern of high correlations generally remained stable or increased across trials, with the exception of the relation between CVLT prediction and postdiction scores. The correlations for verbal fluency and the motor tasks can be interpreted as an indication that the expectations of the study participants, seen in the prediction scores, were in line with their performance appraisal as measured by postdiction scores. Time-lagged correlations, with the predictions of one trial correlated with the postdictions of a previous trial, showed a similar pattern. This suggests that participants used their performance evaluations (postdictions) from one trial to inform their predictions in the subsequent trial. The lower intra-trial correlations on Trial 1 for most tasks lends support to this interpretation.

Understanding the unique characteristics of the CVLT may help to explain the pattern of correlations on this task. Whereas the other tasks in the study, with the exception of Trial 4 (animals) on verbal fluency, repeat the same task over trials, the CVLT required participants to predict and postdict performance on different types of memory tasks, ranging from new learning on Trials 1 and 2, to delayed free recall on Trial 3, and list-word recognition on Trial 4. When the same task was repeated on the CVLT, as on the new learning trials, the NI groups showed the expected increase in correlations. However, this only offers a partial explanation, as the correlations for the PD group showed a slight drop over the two trials. Group differences in the relation between prediction and postdiction scores on this demanding task were evident. The greatest discrepancy in the correlations for the different groups occurred in Trial 3 (delayed recall), where the correlations of the PD group dropped to $\underline{r} = .23$, relative to the correlations for

the combined NI group of $r = .65$. Correlations on Trial 4 (recognition) showed even more dramatic change for the PD group, dropping to a point where virtually no relation was apparent between prediction and postdiction scores. An examination of the means for the prediction and postdiction scores indicates that while the NI groups predicted an increase of approximately 3 words on the recognition trial relative to the delayed free-recall trial, the prediction for the PD group on the recognition trial only showed an increase of approximately one and half words. On the postdiction condition, all groups reported an increase of approximately 3 words on the recognition trial relative to the delayed free-recall trial. This suggests that while the participants in the PD group realized the utility of the recognition strategy as a memory aid to improve performance on this specific task, they were less able to translate their general knowledge of memory function to bring performance expectations in line with perceptions of outcome. The inclusion of a second recognition trial would be useful in future research to assess this assertion. Given the lower correlations between the prediction and postdiction scores on the second trial of new learning, the PD group would not be expected to show much higher correlations on a second recognition trial. In contrast, it is likely that correlations for the NI groups would improve greatly.

Accuracy of Performance Prediction and Postdiction Scores. In addition to the analysis of the actual prediction and postdiction scores, the accuracy of these measures was of interest. The literature that has explicitly examined the effects of aging on the ability to monitor performance is largely limited to investigations regarding memory. Consistently, the research based on samples under the age of 75 years has found that on-

line monitoring of memory function remains relatively constant until the seventh decade (Hertzog et al., 1996; McDonald-Miszczak et al., 1994). In addition to extending the developmental time-line to examine age-related change in metamemory in the later decades of the lifespan, the current study included examination of the ability to monitor performance on selected tasks of executive and motor functioning. Given the expected age-related changes in executive functioning, it was hypothesized that monitoring abilities of NI old-old adults would show decline relative to their younger counterparts. The NI groups were expected to show a higher level of accuracy than the participants with PD.

Prediction and postdiction accuracy. The relation between actual test performance and the prediction/postdiction scores was first assessed with Pearson product moment correlations. Examination of the prediction/performance correlations showed a similar pattern across groups. While the correlations increased in magnitude across trials for the motor tasks, the pattern of correlations for verbal fluency and the CVLT were less consistent. It must be kept in mind that the changes in correlational patterns for these tasks may be related to task condition, as outlined below. The confounding variability introduced by order effects must also be kept in mind as a possible alternative explanation. Nevertheless, examining the pattern of correlations for the participants with PD shows an increase in the magnitude of the correlations across the three phonemic trials of verbal fluency, while the correlation on the semantic trial ($r = .31$) dropped to a level similar to Trial 1 of the phonemic condition ($r = .28$). In other words, while the level of prediction accuracy increased across the first three trials for the PD group, the group was less able to consistently generalize this knowledge to the fourth trial, which demanded a slightly

different set. In contrast, the correlations for the NI groups suggest that they shifted from the phonemic to the semantic condition with little difficulty. The magnitude of the prediction/performance correlations on verbal fluency for the NI old-old group increased between Trials 1 ($\underline{r}$ = .13) and 2 ($\underline{r}$ = .64), then remained stable across the remaining two trials. Similarly, the correlations of the NI young-old were generally stable, with the exception of lower correlations on Trial 2.

On the CVLT, memory condition had a large impact on prediction/performance correlations for all groups, with the correlations dropping to a much smaller magnitude on the recognition trial than those obtained on the previous three free-recall trials. Correlations for the NI young-old participants showed the predicted increase between Trial 1 ($\underline{r}$ = .62) and Trial 3 ($\underline{r}$ = .76) then dropped to $\underline{r}$ = .25 on Trial 4. The correlations for the PD participants were similar, albeit of a smaller magnitude (Trial 1 $\underline{r}$ = -.11; Trial 3 $\underline{r}$ = .33; Trial 4 $\underline{r}$ = .00). Correlations for the NI old-old group generally remained constant for the three trials (Trial 1 $\underline{r}$ = .41; Trial 3 $\underline{r}$ = .48), but also showed a decline for Trial 4 ($\underline{r}$ = .28).

Correlations for the three groups between performance postdictions and actual test scores generally remained stable or showed slight improvement across trials, with the exception of a decline in the magnitude of the correlations on Trial 4 of the CVLT. It is likely of significance that postdictions on the recognition trial of the CVLT were based on a judgement of performance on 32 individual, forced-choice trials, increasing the difficulty of tracking responses, thus reducing the accessibility of the information. It may be that the divided attention required to track the recognition responses (count 1 for yes and 0 for no)

made the performance on this task more difficult to monitor, relative to the recall tasks. As suggested by Hertzog, Saylor, Fleece, and Dixon (1994), task factors influencing the accessibility of information play an important role in performance evaluation. Also consistent with the findings of Hertzog, Saylor, Fleece, and Dixon, the magnitude of postdiction/performance correlations was much greater than those found in the prediction/performance correlations discussed earlier. Overall, the large correlations between the actual performance and the performance evaluations suggest that participants had an immediate awareness of their performance.

To further assess the accuracy of performance predictions and postdictions, a ratio was used to provide a measure of prediction and postdiction scores relative to actual performance. Analysis showed that while there was a trend towards supporting the hypothesis that the prediction accuracy would be related to age, the effect was not statistically significant for the tasks in this study. In fact, the NI old-old group had a slightly higher level of accuracy on the verbal fluency measure than the NI young-old group. This finding suggests that the ability to accurately estimate performance on the range of tasks covered in this study is not highly sensitive to the effects of aging. However, the effect of diagnosis was more pronounced, with the PD group generally over-predicting performance to a greater degree than the NI groups. This trend reached a significant level on two measures, the free recall tasks of the CVLT and on the checkerboard task. Generally, the PD group had estimated a performance level similar to that of the NI groups on cognitive and motor tasks, but the actual performance of the PD group fell short of this mark. The CVLT and the checkerboard task provide interesting

examples. While participants with PD predicted that they would recall fewer words than the NI groups over the three trials (i.e., NI young-old M = 32.43, SD = 7.69; NI old-old M = 30.10, SD = 7.62; PD M = 26.84, SD = 5.57), the predictions remained significantly less accurate than the NI counterparts. On the checkerboard task, despite the difficulties with motor movement inherent in PD, the PD group estimated that the number of checkers correctly placed would be similar to the number placed by the NI group (i.e., NI young-old M = 63.23, SD = 8.24; NI old-old M = 54.95, SD = 8.12; PD M = 45.60, SD = 9.27). As expected, the performance of the PD group fell significantly short of this expectation. In summary, the effect of PD on the ability to accurately predict performance was found to be task-dependent. While it could be expected that people with PD may not readily perceive memory declines, it was somewhat surprising that they would significantly over-predict performance on a motor task. In a closer examination, contrasting the types of tasks where the PD group showed a similar level of accuracy to the NI groups (i.e., verbal fluency and handwriting), with the tasks where the PD group was less accurate (i.e., CVLT and checkers), suggests a possible explanation for these findings. First, the tasks of verbal fluency and backwards handwriting are novel tasks. The predictions on these tasks were similar for all groups. Second, the CVLT, assessing memory, and the checkerboard task, assessing object placement, tasks were more familiar. On the tasks of memory and object placement, where the participants could be expected to draw on their fund of task-specific knowledge, the participants with PD did not anticipate any decline in their performance relative to the NI participants. Again it appears that the PD group had greater difficulty translating their experience into accurate expectations.

As all groups showed a tendency to over-predict their level of performance, it may be that the estimates of the PD group are simply an exaggeration of the general trend. The only exceptions to this trend were found in the semantic trial of verbal fluency and the recognition trial of the CVLT. Under-predictions in these two instances suggest that the participants were unaware of the performance advantage provided by broader category structure on the verbal fluency measure and the recognition cueing on the CVLT. It is also possible that an inability to adjust predictions to accommodate changes in task requirement may be associated with age-related changes in the executive system. It would be necessary to replicate these findings with a sample of young adults to test this hypothesis.

An examination of the prediction estimates over similar trials for each task showed an upgrading of prediction accuracy for all groups. The largest improvement in accuracy was found between Trials 1 and 2 on most tasks, with a relatively high degree of accuracy maintained for the third trial. Specifically, on the phonemic conditions of verbal fluency (F,A,S), prediction accuracy was found to be statistically similar across groups, with all groups over-predicting their level of performance. However, an examination of the means presented in Table 20 shows that while all groups upgraded their predictions to a highly accurate level on Trial 3, the mean predictions of the PD group were slightly more accurate than those of the NI young-old group. As well, while all groups underestimated their performance on the semantic condition, the estimates of the PD group were slightly more accurate than the NI groups. This suggests that the ability to monitor immediate performance changes little with age, and is largely resistant to the neuropathological

effects of PD. Postdiction accuracy scores were also used as a measure of on-line monitoring. Consistent with the findings discussed in the previous section, the groups were generally equivalent in their ability to accurately assess their performance. The only exception was found on the handwriting task, where the PD participants significantly over-postdicted their performance on the second trial, resulting in a significant effect for diagnosis.

Overall, the level of postdiction accuracy achieved on Trial 1 of the motor tasks, and maintained across trials was nearly perfect. In contrast, highly accurate postdictions were not achieved on the verbal fluency task until the second trial, and on the memory task until the third trial. Differential accuracy in performance monitoring appears to be determined by the nature of concreteness the task affords. Participants could see the results of their efforts on both the checkerboard and the handwriting tasks, allowing them to accurately monitor performance from the first trial. Whereas, monitoring performance on the cognitive tasks of verbal fluency and free recall was more difficult. A high level of accuracy was only achieved once experience was gained on the task over trials. This would suggest that the ability to monitor on-line performance remains stable well into old age and it is largely unaffected by PD, despite deteriorations of the cortico-striatal pathways. Nevertheless, the dichotomy of the results with participants achieving a higher level of accuracy on the first trial of the motor tasks than that achieved on the first trial of the cognitive tasks may indicate subtle effects of decline in the executive processes related to metacognition. Future research including a younger sample would be useful to test this

hypothesis. If this is the case, one might expect that young adults would achieve a similar level of accuracy on the first trial of both cognitive and motor tasks.

Given the upgrading of both prediction and postdiction accuracy across trials on many of the measures, it was expected that an examination of the relation between prediction and postdiction accuracy scores would show correlations of increasing magnitude across trials. Pearson product moment correlations were used to examine the relation between these two measures. Overall, the hypothesis was supported with the correlations showing a higher degree of relation between prediction and postdiction accuracy across trials. An exception to this pattern was noted on the CVLT, where the correlations on Trial 3 (delayed recall) were small for the PD group, despite the expected increase in magnitude between Trials 1 and 2. The largest correlations were found on the self-generated sorting trial of the CCST, with prediction and postdiction scores close to the same for all participants. Generally, the smallest correlations were found in the motor tasks where the relations between predictions and postdictions on Trial 1 were either very small (i.e., $r = .01$ for the PD group on the handwriting task) or inversely related (i.e., $r = -.40$ for the NI old-old group on the handwriting task). For both the checkerboard and the handwriting tasks, postdiction accuracy was high on Trial 1, while the prediction accuracy was less so, likely accounting for the low correlations. These results are suggestive of dual processes. On the one hand, postdictions seem to be a process of on-line monitoring of immediate performance. On the other hand, predictions appear to be determined by a process based on a perception of the ability to meet tasks requirements and the ability to

draw on similar past experience. As such, it could be expected that prediction accuracy would draw on similar processes to those which generated the questionnaire responses.

Questionnaire Responses

As the questionnaire data measuring memory self-efficacy have been shown in previous research to be highly correlated with prediction performance on memory tasks (Hertzog, Saylor, Fleece, & Dixon, 1994), Pearson product moment correlations were computed to determine the relation between performance predictions and self-efficacy across the various study tasks. Hertzog, Saylor, Fleece, and Dixon report correlations ranging from .30 to .36 between predictions on a word-list recall task and scores on the MIA Capacity and Frequency of Forgetting scales across three trials, using a written format. In contrast to this earlier research, the present study generally found smaller correlations between oral recall of a word-list (i.e., CVLT) and the memory self-efficacy, possibly due to the different testing formats. In the current study, the magnitude of the correlations increased over repeated trials. This was particularly true for the NI young-old group where positive correlations ranged from .10 on the first trial to .27 on the fourth (recognition) trial. It is of interest that the pattern of correlations appeared to vary by age. While the magnitude and direction of the correlations between the CVLT and the Metamemory questionnaire were of medium size and in the expected direction for the NI old-old group, they were uniformly small and in the opposite direction for the NI young-old group. The correlations for the PD group were smaller than those of the NI old-old group, but they showed a similar level of consistency, with a higher level of daily difficulty related to lower prediction scores. The pattern of the correlations suggests that the

relation between performance predictions and systemic knowledge was weak for the younger participants in the study, and somewhat more robust for the NI group over the age of 75 years. Expectations and memory self-esteem were more congruent for this group than the others, and the increasing magnitude of the correlations over repeated recall trials suggests that self-perceptions of memory performance were reinforced with increased task experience.

Overall, correlations of the Metamemory questionnaire with performance predictions on executive function (i.e., verbal fluency) and motor (i.e., checkerboard and handwriting) tasks were generally of similar magnitude or smaller than the correlations with CVLT predictions. An interesting exception occurred in the PD group where the correlations with Trial 1 of the handwriting and checkerboard predictions were not only the highest ($r = .37$ and .32, respectively), but were also the only task predictions that were positively correlated with the Metamemory questionnaire. One interpretation of this could be that while these participants were acutely aware of motor difficulties, hence expecting a poor performance on motor tasks, they maintained a positive sense of memory self-efficacy.

Correlations of the Metamovement questionnaire with performance predictions on motor tasks found most correlations to be negative, as expected, with higher scores on the questionnaire, indicating a greater perception of problems in daily life, related to an expectation of lower performance on the motor tasks. Notably, the pattern of correlations differed by diagnosis. The relation between predictions of motor performance and reported daily performance on motor tasks was the lowest on Trial 2 for both of the NI

groups. In contrast, correlations for the PD participants started at a lower magnitude on Trial 1 and increased across trials for both tasks to reach a moderate size. As a result, performance expectations were at a higher level of congruency with daily life on the third trial than they were prior to gaining the task specific experience. Correlations of the Metamovement questionnaire responses with performance predictions on verbal fluency and the CVLT were low for both of the NI groups and somewhat higher for the PD group, particularly on the CVLT. However, it is of interest that the correlation for the PD participants between CVLT Trial 1 predictions and the Metamovement questionnaire responses was relatively high, positive, and of a similar magnitude as the correlations with Trials 2 and 3 of the motor tasks. This indicates that people who were reporting a high level of motor problems in daily life expected to recall the greatest number of words on the first trial of the list-learning task. A complicating factor across the groups was that the correlations failed to yield a predominately positive or negative pattern.

Overall, these results lend support to the hypothesis that the perception of daily functioning and task prediction may be separate, although related aspects of metacognition. While both measures rely on monitoring behaviour, questionnaire responses draw on the variety of experiences with similar tasks which have been acquired over the lifetime. In addition to tapping self-efficacy (see Dixon, Hultsch, & Hertzog, 1988), questionnaire responses are dependent on the past recollection of performance. In contrast, as postulated by Hertzog, Saylor, Fleece, and Dixon (1994), task appraisal is likely to have a more prominent role in prediction than vague memories of past performance.

Correlations of Metamemory responses for the NI young-old group with both prediction and postdiction scores were uniformly positive, although correlations with the postdiction scores were of greater magnitude. This pattern indicates that people who reported greater memory problems in daily life expected to have a higher level of performance on the list-learning task, and they had higher postdictions. It seems clear that this group did not generalize their perception of daily memory performance to expectations or estimations on the list-learning task. However, the converse was true for the NI old-old and the PD groups, as correlations for both groups were generally negative. While the magnitude of correlations between the Metamemory questionnaire and the prediction and postdiction scores were similar for the NI old-old group, the correlations between the Metamemory questionnaire and the postdicitons scores of the PD group generally declined compared to the correlations with the prediction scores. It may be that the overall memory schema or self-efficacy reflected in the questionnaire responses is more closely related to perception of task performance (i.e., postdictions) while the predictions rely on more task-specific judgements. Correlations of Metamemory scores with performance postdictions on verbal fluency and the motor tasks were smaller than the correlations with the CVLT and failed to show a consistent positive or negative pattern.

The NI groups showed little relation between performance postdictions on motor tasks and perceptions of daily motor function, as measured by the Metamovement questionnaire. Correlations between postdictions on motor tasks and the Metamovement questionnaire were generally small for the NI groups, although they were in the expected direction. The PD group showed a slightly different pattern. While correlations remained

negative, they increased in magnitude, suggesting a moderately sized relation between perception of motor function in daily tasks and immediate, task-specific perception on motor tasks for participants with PD. These results suggest that the participants with PD may be attending to motor performance both in daily life and on study tasks with more care than they are applying to cognitive tasks. This may be simply due to a general understanding that PD has a detrimental impact on motor function, with little understanding of the expected cognitive impact. Alternatively, it may be that maximal attentional resources are being focused on the area of most concern, reducing the availability of resources to monitor cognitive performance. This may also be true for the NI old-old group with tasks of memory as both predictions and postdiction correlations with the Metamemory questionnaire were higher than other correlations for this group.

Group differences in systemic awareness, as measured by the Metamemory and Metamovement scores, were expected to show a similar pattern to that found in the analyses of on-line awareness. The results of the motor tasks were not expected to be significantly different than those from the memory tasks. In one of the few studies to compare on-line and systemic awareness of cognitive and motor function, McGlynn and Kaszniak (1991) failed to find differences between these factors of metacognition in Huntington's patients. In the present study, group differences in memory self-efficacy were not apparent, despite differences in actual memory performance, predictions, and postdictions on the CVLT, all of which showed higher levels of performance in the NI groups as compared to the PD groups. In other words, while the participants with PD were aware that they were having greater difficulty recalling and recognizing list words

than the NI participants, they did not perceive themselves to have greater difficulty with daily memory tasks. In contrast, the responses on the Metamovement questionnaire showed that the PD group perceived a greater degree of difficulty with daily motor tasks than their NI counterparts, a perception supported by their performance on motor tests. Taken together, these results suggest that while the participants with PD were well aware of visible motor problems, their awareness of memory deficits was more limited. However, as reviewed earlier, the prediction and postdiction scores of the PD group were lower than the NI young-old group on the handwriting task and only the postdiction of checkerboard performance was lower than the NI groups. The NI old-old group also perceived a greater level of motor difficulties than the NI young-old group, similar to the performance on motor tasks. While on-line awareness of performance appears to have elements that overlap with systemic awareness, the two measures of metacognition appear to be tapping different factors.

Executive Functioning and Task Performance

Frontal system dysfunction, commonly manifested in the early stages of PD, was expected to have a detrimental impact on performance on memory and motor tasks. Comparing the performance of a group of nondemented PD participants with matched NI elderly participants, Bondi, Kaszniak, Bayles, and Vance (1993) found differences on tasks of learning, memory, and visuospatial construction were accounted for by the differential efficiency of the frontal systems. Similarly, Troyer, Graves, and Cullum (1994) found learning and memory to be largely accounted for by performance on tasks of executive function in a sample of healthy, elderly adults. In the present study, multivariate

analyses of covariance were used to examine the hypothesis that executive functioning was related to performance on memory and motor tasks. It was expected that group differences in performance would no longer be significant once the variance associated with executive function was removed from the CVLT and the motor tasks of checkerboard and handwriting. Similar to previous research, the current study found that differential group performance on the CVLT was related to executive function, as measured by verbal fluency and the CCST. Once the variance associated with the measures of verbal fluency and the CCST was removed from the CVLT, group differences on this list-learning task were no longer apparent. Conversely, the CVLT was not shown to account for a significant proportion of variance in the executive measures. Clearly, the role of executive functioning in memory tasks is a central component, supporting the findings of Troyer, Graves, and Cullum, as well as Bondi and his colleagues. However, concept formation, planning, and organization appeared to have less of an impact on the motor tasks as the measures of executive functioning were unable to account for group differences on these tasks. On tasks of fine motor control and dexterity, extra-experimental factors, such as the speed of hand movements and manual dexterity may be stronger determining factors in performance than the abilities associated with executive function.

Executive Functioning and Metacognition

Theoretically, executive functioning and metacognition are integral components of the executive control system, with the ultimate task of producing effective, goal directed behaviour. The independent lines of research discussed above indicate that each of these

components of the executive control system shows a variable pattern of age-related decline and are detrimentally influenced by the effects of PD.

To promote a better understanding of the executive control system, the relation between executive functioning and metacognition was examined. Congruent with the analysis of metacognitive components presented earlier, the pattern of group differences on the metacognitive tasks of prediction and postdiction accuracy was differentially related to task. Specifically, executive functioning accounted for a significant proportion of the variance associated with group differences in the ability to accurately estimate performance on the free recall list-learning task. In other words, once the variance associated with the executive tasks of verbal fluency and CCST was taken into account, CVLT prediction accuracy scores were equated across the groups. In contrast, prediction accuracy on the checkerboard task remained dependent on group membership after the variance associated with the executive tasks was removed from the analysis.

While the ability to accurately predict performance on the CVLT and checkerboard tasks was dependent on group membership, group effects for postdiction accuracy were limited to the handwriting task. In this case, removing the variance associated with verbal fluency and the CCST equated the postdiction accuracy of handwriting performance across the groups.

It may be that the ability to focus attentional resources, establish a plan of action, and to organize cognitive activity to meet the established goals had more of an impact on the ability to accurately predict performance on a memory task, than on a task demanding accurate gross motor movements. Alternatively, it must also be considered that it was

relatively easier to count the number of checkers placed during the checkerboard task than to keep track of the number of words recalled in an oral format on the memory task. As such, accurate prediction on the checkerboard task may have become routine more quickly than the memory task, placing a lower demand on the resources available in executive function than those required to complete the memory task. In terms of the Stuss (1991a) model, this would mean that metacognitive module draws relatively little from the module responsible for executive function on motor tasks, with characteristics similar to those of the checkerboard task. Conversely, on list-learning tasks much of the information processed by the metacognitive module appears to have been first processed in the executive function module. This would suggest that impairment of the abilities associated with executive function should influence the expectations of memory performance, and possibly other cognitive activities, before it has a significant impact on the ability to influence the expectations of motor function. More to the point, as the three groups were statistically equivalent in their ability to monitor performance on most tasks, as measured by postdictions, faulty integration of this knowledge with current task demands on the CVLT appears to be a contributing factor to group differences on the memory prediction tasks.

The results of the ANCOVA found that the abilities associated with executive function play a significant role in accurately monitoring handwriting performance, the only task presenting group differences in postdiction accuracy. While the ability to monitor performance appears to show few effects of age or PD, these results suggest that subtle differences in performance may be related to changes in executive function.

Conclusion

To this point, research on the executive system has primarily proceeded along two independent lines of investigation. One line of research has explored changes in executive functioning relate to age and the pathological processes associated with PD. The other line of research has examined age-related changes in metamemory. As a result, little is known about the relation between these two constructs and how changes in one area of the executive system impact the other. The goal of this study was to contribute to the theoretical and clinical understanding of the executive control system.

First, changes in executive functioning, memory, and motor performance related to age and the pathological processes associated with PD were examined. Overall, results showing age-related changes in performance were restricted to one measure of executive functioning and to performance on motor tasks. NI old-old participants had more difficulty generating novel concepts on the CCST and producing the target movements than the NI young-old group. This research increases scientific understanding of the developmental process of aging by extending the time-line into the later decades of the lifespan. Replication of these resuls can provide the knowledge base needed to continue to inform government policies and to provide the necessary supports to maximize independence in old age. The participants with PD showed a lower level of performance in all three areas of functioning. The participants with PD had more problems on tasks of initiation, concept formation, organization, memory, and motor function. Further investigation of these issues contributes to a scientific understanding of the cognitive changes associated with PD. On a pragmatic level, this research may be useful in the

design of care and rehabilitation programs implementing concrete goals, clear organizational structure, and memory supports, in addition to the more traditional supports for motor problems.

Second, age-related differences in awareness of cognitive and motor performance were examined, and contrasted to changes associated with PD. Analyses found age-related change in performance predictions on the CCST and the handwriting task, while the effects of PD were evident in lower predictions on the CVLT and the handwriting task, relative to the NI groups. Participants in all groups demonstrated an upgrading of predictions over trials, indicating that task experience was used to inform performance expectations. As the PD group had lower levels of performance than the NI groups across the three areas of functioning, lower prediction scores would be needed to accurately reflect functional ability.

Correlations conducted to investigate the relation between performance prediction and actual performance scores found that the magnitude increased across similar trials for all tasks. These results indicate that as participants gained experience with the task, performance expectations became more closely related to actual performance. A more detailed analysis of the prediction/performance ratio for each task found that age had a limited effect on prediction accuracy, with NI old-old participants slightly more accurate on verbal fluency than the NI young-old. This may be an indication that the factors contributing to performance expectations, such as task knowledge and self-efficacy, are not highly sensitive to the effects of aging. In contrast, the findings of higher levels of inaccuracy related to PD were somewhat less optimistic. The participants with PD

significantly over-predicted their level of performance on the CVLT and the checkerboard task, and had slightly higher over-predictions than the NI groups on the tasks of executive function. All participants upgraded their level of accuracy across trials, with the PD group reaching a higher level of accuracy on the semantic trial of verbal fluency than the NI groups. Nevertheless, these results suggest that the participants with PD may be compromised in their awareness of the match between task demands and personal abilities, relative to their NI counterparts. It may be that the cognitive changes have occurred too quickly for the participants with PD to adjust performance expectations. Alternatively, limitations in processing resources, defined by Light (1991) as encompassing the capacity for attention and working memory, as well as speed of cognitive processing resources may be impeding adjustment to cognitive change. In daily life, an understanding of the impact of PD on the match between performance expectations and abilities could be important to adequately support PD patients and to maximize independence.

The results of the analyses of postdiction scores revealed a different pattern relative to the prediction scores. While the NI groups had similar performance expectations on most tasks, performance evaluations were found to be related to age on the CCST and the motor tasks, with the NI young-old group reporting higher levels of performance than the NI old-old group. Also consistent with actual performance, the postdiction reports of the PD group were lower than one or both NI groups for most tasks, with the exception of the CCST. Clearly, expectations frequently did not equal the perception of outcome. All groups showed upgrading of postdictions over the first few trials of the tasks, which appeared to be in line with changes in actual performance.

Correlations between postdiction reports and actual performance scores were generally stable, and higher than the prediction/performance correlations, suggesting that participants had a good immediate awareness of performance efficacy. Postdiction/performance accuracy ratios showed a high level of accuracy for all groups across tasks. The accuracy ratio of the PD group on the second trial of the handwriting task was the only exception. Generally, participants had highly accurate postdictions from the first trial on motor tasks, achieving a similar level of accuracy only after two or more trials on the cognitive tasks. In other words, while participants were readily able to monitor performance on tasks where the results were visible (i.e., motor tasks), it took longer to achieve a comparable level of accuracy on cognitive tasks. One interpretation of this delay in establishing accurate performance monitoring on cognitive tasks may be that the cognitive tasks require a more rigorous dual cognitive process to mentally track performance while mentally generating the product for the task at hand.

To examine the relation between these two measurements of metacognition, correlations between prediction and postdiction accuracy were conducted. Results indicated that correlations were upgraded across trials for the NI groups, suggesting that age had little effect on the ability to adapt performance expectations based on the results of immediate task experience. In contrast, it appeared that the PD group had more problems integrating the knowledge gained from on-line monitoring with expectations. Overall, the correlations for this group were smaller than those for the NI groups, with particular problems evident on the delayed trial of the CVLT as the relation dropped to a near zero correlation.

Examining the relation between Metamemory and Metamovement questionnaire responses with prediction and postdiction measures further augmented understanding of the three measured components of metacognition in this study. Correlations between the Metamemory questionnaire responses and memory predictions were generally found to be weak, particularly for the NI young-old and the PD groups. Participants in the NI old-old group had a higher level of congruence between performance expectations and memory self-efficacy. This finding is an anomaly, as throughout this study the results of the PD group have shown a greater degree of similarity to the NI old-old group than the NI young-old, despite the fact that the ages of the NI young-old participants and the PD participants were similar. It may be that the younger participants, whether they have a diagnosis of PD or not, simply made less use of daily experience when establishing task-specific expectations, than their more senior counterparts. Nevertheless, correlations increased in magnitude over repeated trials for all groups, showing a greater congruence between task expectations and perceptions of daily memory functioning, with increases in task-specific experience.

Correlations between responses on the Metamovement questionnaire and prediction on the checkerboard and handwriting tasks were slightly larger than those between metamemory measures, particularly for the PD group. This group showed moderate correlations between predictions on motor tasks and perceptions of daily motor function, with low expectations on motor tasks correlating with a perception of greater problems on daily motor tasks. It was also of interest to note that the correlations between the first trial of the CVLT and the Metamovement questionnaire, and the motor

tasks and the Metamemory questionnaire were higher than the intra-domain correlations for the PD group and in the positive direction. It may be that for the participants with PD, memory is of less concern relative to motor function, as a higher level of perceived motor problems was related to higher memory expectations, and fewer daily memory problems were related to lower motor expectations. Conversely, this group may have fewer cognitive resources to devote to performance monitoring in domains other than motor performance. As a result, they may be less aware of changes in cognitive function than their NI counterparts.

Correlations between questionnaire responses and performance postdictions showed a small to moderate relation between these two measures of metacognition. As with the prediction/questionnaire correlations, the correlations between the Metamemory questionnaire and the CVLT were larger for the NI old-old group than for the other two groups, and the correlations between motor tasks and the Metamovement questionnaire were larger for the PD group. It may be expected that as people age they become more concerned with memory function, and those with PD focus attention on motor problems, resulting in a greater level of awareness in these respective areas.

Overall, the small to moderate size correlations between task predictions/postdictions and perception of daily functioning, as measured by questionnaires, suggests that a general level of self-efficacy in each domain establishes a third factor of metacognition. Future research to further define this connection, establishing a pattern of similarities and differences across domains, would be of interest.

Analyses failed to reveal differences between the groups in reported daily memory function on the Metamemory questionnaire. However, as expected, the PD group reported more problems with daily motor tasks than the NI groups.

The third goal of the study was to examine the relation between executive function and metacognition. The results confirm the theoretical relationship between cognitive and metacognitive factors of the executive control system involving memory and handwriting, further extending our understanding of the developmental characteristics of this system to include the later stages of the lifespan and the effects of PD. Clinically, the implications of the role of executive functioning on metacognition could be important to people with PD. In this study, where all participants were over the age of 55 years, age-related declines in executive function and memory performance were minimal. At this point, any declines in the executive functioning of NI adults has occurred gradually over a number decades, increasing the probability that strategies to maximize the fit between environmental demands and executive functioning have been implemented as needed. As a result, age-related declines in executive functioning and the concomitant impairment of metacognition are likely to have little effect on the daily life of NI elderly. In contrast, the cognitive changes associated with PD were significantly in excess of that seen in the NI groups, and these changes have occurred over a shorter time frame. In addition, it is likely safe to assume that people with PD focus much of their resources on compensating for obvious motor changes to maximize optimal levels of functioning. As such, the resources available to monitor changes in cognitive performance would be limited. While deficits in executive functioning may be readily apparent, deficits in metacognition may be difficult to

determine. Misperceptions of capabilities can have a negative impact on health, increasing risk of injury due to misremembered information or over-estimates of motor function. A greater understanding of the association between cognitive and metacognitive changes in the executive system may be used to develop compensatory strategies that maximize the independence of people with PD and increase their level of safety.

The results of this study also serve to increase scientific understanding of the relation between executive function and metacognition. In the Stuss (1991a) model presented earlier, the module encapsulating self-awareness and metacognition was represented as hierarchically superior to the module of executive function. In the current study, group differences in metacognition on tasks of memory and handwriting were explained by differences in executive function. However, the converse was not true, as differences in metacognition could not account for group differences on tasks of executive function. While the Stuss model is very broad and leaves one to question where higher cortical functions, such as memory fit into the model, the results of this study provide limited support for this conceptualization. However, a problem arises with the failure of differences on tasks of executive function to account for variability in metacognitive performance on the checkerboard task. These results suggest that executive function may play a greater role in the metacognition of cognitively-laden tasks, such as memory and language, than on less cognitively demanding tasks, where the components are largely routine.

While this study examined two dimensions of the executive control system, executive function and metacognition, future research is needed to identify other

components of this multifactorial construct. The cross-sectional design of this study provided a starting point for assessing the developmental trajectory of the executive control system. However, a longitudinal research design is necessary to confirm that the changes reported in this study are part of the developmental process. Specific questions arising from this study could be addressed by extending the age-range to include young adults. For example, under-estimates of both the semantic condition of verbal fluency and the recognition condition of the CVLT could be due to changes in executive function that occur before the age of 55 years. Including a younger sample could help address this question. In addition to further research examining the relation between metacognition and executive functioning, it would be useful to both clinical and theoretical fields to examine the relation between metacognition and the use of compensation across domains. In this study, while the participants with PD had lower performance on memory tasks than their NI counterparts, they reported fewer problems in daily memory functioning and they predicted a similar level of performance on the study measures. Further, as problems with daily motor tasks increased, performance expectations on the list-learning task increased and reported problems with daily tasks of memory decreased. As people are not known for implementing compensatory strategies in areas where they anticipate performing at an adequate level, it seems that the people with PD may be unlikely to use memory supports when they could be beneficial (i.e., a reminder to take medications or keep appointments). Research into the relation between metacognition and compensation is needed to test this assumption.

To summarize, this study focused on two constructs of the executive control system, executive functioning and metacognition. First, changes associated with aging and PD were examined within each of these areas, then the relation between executive functioning and metacognition was assessed. While the performance of the NI participants was similar on verbal fluency, a measure of executive function, and on the CVLT, a measure of memory, the NI young-old performed at a higher level on the CCST and on the motor tasks relative to the NI old-old group. The participants with PD performed at a lower level in each of these three areas. The three measures of metacognition, performance predictions, postdictions, and questionnaire data each yielded distinctive results. The accuracy of performance expectations was largely resilient to the effects of aging. However, the effects of PD were evident on tasks of memory and gross motor control. The study groups were equivalent on measures of postdiction accuracy on most tasks, with the exception of handwriting where the accuracy level of the PD group was lower than that of the NI groups. While a high level of accuracy was achieved on the first trial of motor tasks, two or three trials were required to achieve a similar level of accuracy on the cognitive tasks. Perceptions of daily memory function were similar for the groups in the study. In contrast, the PD group reported greater difficulty with daily motor tasks than the NI groups. Finally, the results confirmed the theoretical relation between executive function and metacognition in the areas of memory and handwriting, but executive function was shown to have little impact on the metacognitive processes involved in a routine gross motor task. While this research is limited by the constraints of the sample, it offers preliminary evidence that the relation between executive function and

metacognition is domain specific, with a stronger association on cognitively-laden tasks relative to the routine tasks.

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Appendix A

Code Number:_____

Movement Questionnaire

DIRECTIONS:

People engage in many different types of movement throughout the day, and different people use different kinds of movement. For example, some people jog daily, whereas others do not. Some people write very quickly, whereas others do not.

In this questionnaire we would like you to tell us about your use of movement and how you feel about it. There are no right or wrong answers to these questions because people are different. Please take your time and answer *each* of these questions to the best of your ability.

Each question is followed by five choices. Draw a circle around the letter corresponding to your choice. Mark *only one* letter for each statement.

The questions ask your opinion about movement-related statements; for example:

I can easily zipper my coat.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

In this example you could, of course, choose any *one* of the answers. If you agree strongly with the statement you would circle a. If you disagree strongly you would circle e. The b and d answers indicate less strong agreement or disagreement. The letter c answer gives you a middle choice, but don't use the c unless you really can't decide on any of the other responses. Choose the answer that comes closest to what is *usually* the case for you. Don't worry if there are some exceptions.

Keep these points in mind:

(a) Answer *every* question, even if it doesn't seem to apply to you very well.

(b) Answer as honestly as you can what is true for *you*. Please do not mark something because it seems like the "right thing to say".

Movement Questionnaire (continued)

1.	It is easy for me to turn bathroom taps on and off.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
2.	I usually need help buttoning my clothes.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
3.	I have trouble grasping small coins.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
4.	I can easily write a handwritten note.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
5.	I have trouble climbing out of my bath.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
6.	I never need help with bathing or showering.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
7.	My hand shakes when I try to drink from a cup	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

Movement Questionnaire (continued)

8.	I have difficulty walking up a flight of stairs.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
9.	My penmanship is very good.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
10.	I can walk as quickly as when I was younger.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
11.	I have trouble rising from a reclining position.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
12.	It is easy for me to cut-up my food at dinner.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
13.	It is difficult for me to sign my name.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly

Movement Questionnaire (continued)

14.	Food seldom falls from my fork when I am eating.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
15.	Cutting paper with scissors is difficult for me.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
16.	I never have trouble tying my shoe laces.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
17.	I can comb my hair without any difficulty.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly
18.	I can insert a key into a lock without difficulty.	a. agree strongly b. agree c. undecided d. disagree e. disagree strongly