Intraindividual Variability and Severity of Cognitive Impairment

by

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ABSTRACT

Previous research has indicated that intraindividual variability has the potential to be an indicator of neurobiological compromise (Fuentes et al., 2001; Hultsch et al., 2000; Hultsch et al., 2002; Lawton, Parmelee, Katz & Nesselroade, 1996; Li & Lindenberger, 1999; Li et al., 2001; Murtha et al., 2002; Strauss, MacDonald, Hunter, Moll & Hultsch, 2000). The present study investigated whether inconsistency in cognition was related to the extent of cognitive impairment in community dwelling older adults. Healthy volunteers with no evidence of dementia were administered 5 cognitive tasks (perceptual speed, reasoning, episodic memory, verbal fluency and vocabulary) and these results were used to create three groups: NCI (no cognitive impairment), CIND-Single (adults down 1SD+ in one domain) and CIND-Multiple (adults down 1SD+ in 2 or more domains). Participants were tested over five weekly sessions on a variety of RT measures. Results indicate that intraindividual variability in cognition was sensitive enough to discriminate between mild cognitive impairment and normal neurological functioning as well as between severities of mild cognitive impairment. Further, intraindividual variability was demonstrated as consistent across measures, positively related to task complexity and negatively related to overall level of performance. The results suggest that intraindividual variability in cognitive performance is relevant to the study of persons with mild cognitive impairment, not only as an indicator of overall performance levels but also as a potential marker for early treatment.

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CHAPTER 1

Introduction

In the field of psychology, the primary approach to studying developmental change has been to investigate the average level of performance on a specified domain as a function of age. Although this approach has provided a great deal of information concerning how humans develop across the lifespan, it assumes that behaviours are stable estimates at each point in time and change across time occurs in the same manner for all individuals (Hultsch, MacDonald & Dixon, 2002; van Geert, 1997). However, growing evidence indicates that a great deal of behavioural variability exists within age groups and individuals (Hultsch, MacDonald, Hunter, Levy-Bencheton & Strauss, 2000; Hultsch et al., 2002; Murtha, Cismaru, Waechter & Chertkow, 2002; Nesselroade, 1991; Rabbitt, Osman & Moore, 2001; West, 1999). Thus, there needs to be a new approach to studying developmental change, one which can account for variability.

Nesselroade (1991) discussed two types of developmental change that account for behavioural variability in developmental research. The first, intraindividual change refers to enduring changes that are the result of learning and maturation (Nesselroade, 1991). The second refers to transient or relatively short-term changes that occur rapidly and are reversible (Nesselroade, 1991). This type of developmental change has been labeled intraindividual variability (Nesselroade, 1991) and is the focus of the present study.

The concept of intraindividual variability challenges the traditional assumption that any true level of a variable has a characteristic stability over time and across individuals (Nesselroade, 1991; van Geert, 1997). Rather, this concept implies that a

score occurs within a state space that is characterized by the levels of a set of variables which define the particular event/time frame during which the score was achieved as well as the level of the trait that is being measured (Nesselroade, 1991; van Geert, 1997). Thus, the examination of how variable individuals are may in fact better represent how they are functioning overall rather than as typically done by averaging their performance.

The Properties of Intraindividual Variability

In order to understand intraindividual variability's utility in investigating developmental change, a brief review of its properties is in order. First, intraindividual variability is a lawful phenomenon (Fiske & Rice, 1955; Hultsch et al. 2000; Jensen, 1992; Li, Aggen, Nesselroade & Baltes, 2001; Rabbitt et al., 2001). In other words, the variability in an individual's response to one stimulus is due to some factor within that individual rather than a result of random error in measurement. For example, Hultsch et al. (2000) found that in older adults, intraindividual variability was stable across time (e.g. both within and across test occasions) and across cognitive domains (e.g. measures of reaction time and episodic memory), substantiating the lawfulness of intraindividual variability.

Second, despite its relationship to overall performance level, intraindividual variability is an independent source of variance from the overall performance level (Jensen, 1992). Hultsch et al. (2000) found that after partialling out overall performance level, substantial intraindividual variability remained. Other studies have reported similar findings (Burton, Hultsch, Strauss, & Hunter, 2002; Fuentes, Hunter, Strauss, & Hultsch, 2001; Hultsch, MacDonald & Dixon, 2002; Strauss, Slick, Levy-Bencheton, Hunter, MacDonald & Hultsch, 2002).

A third property of intraindividual variability is that it is independent of systematic within-person variability, which is related to practice and/or learning effects. Studies have found that sizeable intraindividual variability remained after systematic within-person variability associated with practice, materials, and learning was statistically removed (Burton et al., 2002; Fuentes et al., 2001; Hultsch et al., 2000; Strauss et al., 2002). Thus, intraindividual variability does not reflect change due to systematic within-person variability resulting from practice, learning or materials.

The Meaning of Intraindividual Variability

While the properties of intraindividual variability are well established, the meaning of variability in cognitive functioning is less clear. Jensen (1980) speculated that intraindividual variability was due to random neural oscillations in excitatory potential. These random neural oscillations caused variability in reaction times as a result of the delays caused by the subthreshold oscillations at the point of stimulus presentation (Jensen, 1980). The more neural elements a response required, the greater the potential for delays and thus, Jensen (1980) indicated that for more complicated tasks, greater variability could be expected. Indeed, some subsequent studies have found that reaction time tasks of greater complexity do elicit greater intraindividual variability (Jensen, 1987; Hultsch et al., 2000; Murtha et al., 2002).

Jensen later proposed that the source of the variability in the nervous system could be the degree of neuronal myelination (1992). Myelination of neurons is a process that continues from infancy to early adulthood and de-myelination is thought to begin in late adulthood (Jensen, 1992). According to Jensen (1992), individual differences in the degree of myelination could be the source of intraindividual variability as myelination

prevents excitation from being transmitted laterally between neurons. The greater the lateral transmission of excitation, the greater area of the brain becoming activated and thus, the greater chance of noise in the system (Jensen, 1992).

Hendrickson (1982) also speculated as to the meaning of intraindividual variability, proposing the neural noise theory. Random errors in neural transmission, which Hendrickson proposes are molecular recognition errors at the synapse, are the source of intraindividual variability and are characteristic of the individual (1982). Hultsch et al.'s (2000) finding of the stability of intraindividual variability across tasks and occasions supports the proposal that response variability is characteristic of an individual, however, it does not speak to Hendrickson's theory more so than any other.

More recently, Li and Lindenberger (1999) proposed that intraindividual variability could be due to age-related decline in catecholamine concentrations. Catecholamines are thought to enhance " the responsivity of a neuron to other incoming afferent signals," (Li & Lindenberger, 1999, p. 117). Thus, with the aging-related reduction of catecholamines in the system, noise in the brain increases which then causes variability in response (Li & Lindenberger, 1999). Work with animal and human models of dopaminergic depletion supports this theory (for review, see Li & Lindenberger, 1999). Further, this theory provides an underlying mechanism for both Jensen's (1980) and Hendrickson's (1982) theories of 'errors' within the neuronal system.

Overall, the theories suggest that intraindividual variability is a characteristic of an individual's nervous system. Thus, one would predict that those with neurobiological compromise would be more variable than those with normal nervous system function. Several studies have found this to be the case. For example, individuals with Alzheimer's

disease, epilepsy, and traumatic brain injuries as well as older individuals have been shown to be more inconsistent across time (e.g. seconds, minutes, weeks) than adults without neurological compromise (Fuentes et al., 2001; Hultsch et al., 2000; Hultsch et al., 2002; Lawton, Parmelee, Katz & Nesselroade, 1996; Li & Lindenberger, 1999; Li et al., 2001; Murtha et al., 2002; Strauss, MacDonald, Hunter, Moll & Hultsch, 2000). Further, study of neurological comprise associated with head injury has shown that inconsistency increases with increasing severity of injury (Stuss, Stethem, Hugenholtz, Picton, Pivik & Richard, 1989). Thus, the evidence suggests that intraindividual variability is an indicator of neurobiological integrity such that those with neurobiological compromise are more variable than normal functioning individuals.

An indicator of neurobiological integrity has the potential to be useful in studying neurobiological diseases in their early stages, which are currently difficult to detect to the mild nature of the deficits. In particular, the existence of a long preclinical phase of dementia has been firmly established (Bondi, Monsch, Galasko, Butters, Salmon & Delis, 1994; Fabrigoule, Rouch, Taberly, Letenneur, Commenges, Mazaux, Orgogozo & Dartigues, 1998; Touchon & Ritchie, 1999). However, the detection of the earliest stages during which very little cognitive impairment has occurred is difficult due to the overlap with changes occurring during normal aging (Bondi et al., 1994; Morris & Price, 2001). The importance of early detection of cognitive changes associated with pathology has increased with the advance of potential medical treatments of dementia. These medications may serve to slow down the progression of the disease or prevent the development of the full symptomatology (Doraiswamy, 2003). Thus, a measure, which is sensitive to the early stages of dementia and could aid in early diagnosis, may increase

the possibility of maintaining the individual's quality of life or at minimum, extending the period prior to decline.

The Present Study

The present study focused on individuals with mild cognitive impairments that do not meet the criteria for dementia. Individuals with mild cognitive impairments have been found to be at increased risk for developing dementia (11-14% per year) compared to individuals without cognitive impairments (1-2% per year) (Bozoki, Giordani, Heidebrink, Berent & Foster, 2001; Morris, Storandt, Miller, McKeel, Price, Rubin, & Berg, 2001; Palmer, Wang, Backman, Winblad & Fratiglioni, 2002; Petersen, Smith, Waring, Ivnik, Tangalos & Kokmen, 1999; Tuokko & Frerichs, 2000; Tuokko, Frerichs, Graham, Rockwood, Kristjansson, Fisk, Bergman, Kozma & McDowell, 2003; Wolf, Grunwald, Ecke, Zedlick, Bettin, Dannenberg, Dietrich, Eschrich, Arendt & Gertz, 1998). However, many individuals classified as having mild cognitive impairment not dementia (CIND or MCI), do not progress to dementia, remaining stable or improving over time (for review, see Palmer, Fratiglioni & Winblad, 2003). From this, one can conclude that the classification of CIND encompasses a heterogeneous group. The classification is currently not specific enough to be useful in identifying those individuals who truly have neurobiological changes that preclude the development of dementia and thus, would benefit from early treatment.

A potential avenue for increasing the specificity of the diagnosis of mild cognitive impairment is intraindividual variability. The purpose of the present study was to examine intraindividual variability in cognitive performance in adults with no impairment, impairment in a single cognitive domain and impairment in multiple

cognitive domains. In the investigation, we attempted to examine six major questions. The first question is whether intraindividual variability is sensitive to mild cognitive impairments. If intraindividual variability reflects neurobiological functioning, as previously discussed and mild cognitive impairments are a result of changes in neurobiological functioning, it was predicted that individuals who are impaired in a single cognitive domain or in multiple cognitive domains would be more variable than normal individuals.

The second question is whether intraindividual variability is sensitive to severity of cognitive impairment. Potentially, individuals with impairments in multiple cognitive domains have greater severity of neurobiological dysfunction and as such, were predicted to show greater intraindividual variability than those with impairment in a single domain.

The third question pursued by this study is intraindividual variability's relationship to overall level of performance in individuals with mild cognitive impairment. If intraindividual variability is an indicator of neurobiological function, one would expect that overall performance would be impacted by the same neurobiological status as the variability. Prior research has found that intraindividual variability was related to overall level of performance such that higher levels of variability were associated with lower overall performance on the tasks (Burton et al., 2002; Hultsch et al., 2000; Hultsch et al., 2002). Thus, it was predicted that higher levels of variability would be associated with lower levels of performance in all groups.

A fourth question to be examined is if intraindividual variability is related to neurobiological function and thus, is an intrinsic characteristic of a person, one would expect that different measures of intraindividual variability would be related to one

another in that a person who is more inconsistent on one measure will also be more inconsistent on another. Prior findings have indicated this to be the case (Burton et al., 2002; Fuentes et al., 2001; Hultsch et al., 2000; Strauss et al., 2002). Thus, it is predicted that different measures of intraindividual variability will be related positively with one another.

A fifth question concerns the complexity of the tasks. As the cognitive demands increase, one would expect that individuals with neurobiological dysfunction would show more variability. Prior research has found that individuals are more variable on complicated tasks such as complex compared with simple reaction time tasks (Hultsch et al., 2000). Therefore, it was predicted with individuals would show greater variability on more cognitively demanding tasks.

The sixth and final question to be examined is the interaction of mild cognitive impairments and age on intraindividual variability. Prior research has found that older individuals show greater variability than younger individuals (Hultsch et al., 2002). It was hypothesized that older individuals would be more variable than younger individuals and that older individuals with multiple domains of impairment will be the most variable.

CHAPTER 2

Method

This analysis was based on cross-sectional data from Project MIND. The overall design of this study consists of bursts of measurement (over weeks) to assess short-term fluctuations in performance that are repeated longitudinally (yearly) to assess long-term changes in cognitive and physical function.

Participants

Participants were community dwelling individuals (age > 64) who responded to a newspaper advertisement soliciting elderly people who were concerned about their cognitive functioning and had not been diagnosed with a neurological disorder. Participants provided demographic and self-reported health information and completed the cognitive tasks (perceptual speed, reasoning, episodic memory, verbal fluency and vocabulary) during a group testing session. During an initial intake interview, participants completed the MMSE (Folstein et al., 1975) and other benchmark cognitive measures (not discussed in this paper) and provided information about their current medications.

Exclusionary criteria for the present study included major medical illnesses (e.g., Parkinson's disease, heart disease, dementia, cancer, brain tumor), severe sensory impairment (e.g. difficulty reading newspaper print size, difficulty hearing a normal conversation, difficulty writing or pressing buttons), extensive drug or alcohol abuse, inpatient psychiatric treatment or a MMSE score less than 24. As well, participants were excluded if they were participants in the Victoria Longitudinal Study from which the present study obtained the norms for its cognitive measures. Finally, participants were

excluded if they scored below 1 SD on all five cognitive tasks and had English as a second language.

Data from 305 participants (208 women, 97 men) from Year 1 were used in the present study. Participants were classified into groups using age and education-based normative values for five cognitive measures (perceptual speed, reasoning, episodic memory, verbal fluency, and vocabulary) from a separate sample. The normative sample was drawn from the Victoria Longitudinal Study of Aging. Participants in the normative sample were community dwelling older adults ranging in age from 65 to 94 years (M= 72.75, SD = 5.55). The average education for the normative sample was 14.57 (SD = 2.95). Data from 445 participants (282 women, 163 men) were used as norms for perceptual speed, reasoning, verbal fluency and vocabulary tasks and data from 194 participants (125 women, 69 men) were used as norms for the episodic memory task.

Participants in the current study were classified as NCI (no cognitive impairment) if they scored within one standard deviation of their age and education-matched peers on all tasks (n = 136). Participants were classified as CIND-single if they scored one or more standard deviations below their age and education-matched peers on one cognitive task (n = 89). Participants were classed as CIND-multiple if they scored one or more standard deviations below their age and education-matched peers on two or more cognitive tasks (n = 80). Participants were then divided into two age groups using the defined categories Mid-Old (MO) (64-73) and Old-Old (OO)(74+).

Overall, participants in the present study showed the typical selectivity of longitudinal samples compared with the general population. The average education of the population was 15.06 years (SD = 3.09) with greater than 77% of participants receiving

12 or more years of formal education. More than 87% of participants rated their health as very good or good relative to a perfect state (M = 4.22, SD = 0.67 on a 5-point scale ranging from 1 = very poor to 5 = very good) and more than 94% of participants rated their health as very good or good (M = 4.47, SD = 0.61) relative to same-aged peers. The average MMSE score of the sample was 28.76 (SD = 1.25). Thus, the sample used in this study was a highly select group of high functioning adults.

Descriptive information on the participants' education and self-reported health is reported in Table 1. A 2(Age) X 2(Gender) X 3(CIND status) multivariate analysis of variance (MANOVA) was used to examine group differences on education and self-reported health. The omnibus effect for Age, F (2, 290) = 7.08, $p < .001$, $\eta^2 = .05$, was significant with univariate analyses yielding significant age differences for education alone, F (1, 291) = 13.05, $p < .001$, $\eta^2 = .04$. The MO group had significantly more years of education than the OO group. Similarly, the omnibus effect for CIND status, F (4, 580) = 4.01, $p < .001$, $\eta^2 = .03$, was significant with univariate analyses yielding significant CIND group differences for education, F (2, 291) = 4.93, $p < .01$, $\eta^2 = .03$. The NCI group was significantly better educated than the CIND-multiple group The CIND-single group did not differ from either the NCI or CIND-multiple group on education. As well, significant CIND group differences were found for self-ratings of health, F (2, 291) = 3.13, $p < .05$, $\eta^2 = .02$. The NCI group rated themselves significantly higher in health than the CIND-multiple group. The CIND-single group did not differ from either the NCI or CIND-multiple group in their health ratings. No other significant group differences or significant interactions were observed.

An analysis of the MMSE scores revealed significant group differences as a function of age, F (1, 299) = 22.16, $p < .001$, $\eta^2 = .07$, and CIND status F (2, 299) = 11.05, $p < .001$, $\eta^2 = .07$. Post hoc analyses on the CIND classifications were assessed using the Bonferroni technique ($p < .05$). All the groups had uniformly high MMSE scores; however, the CIND-multiple group was significantly lower (M = 28.25, SD = 1.50) than both the healthy (NCI) (M = 29.05, SD = 1.06) and the CIND-single group (M = 28.70, SD = 1.12), which did not differ from each other. The OO group had significantly lower (M = 28.40, SD = 1.42) MMSE scores than the MO group (M = 29.04, SD = 1.01). Despite the statistical significance of these differences, a difference of less than one point in MMSE scores is not a meaningful difference in terms of the scale and thus, was not covaried out in this study. In addition, covarying out MMSE scores may potentially remove a defining feature that distinguishes the groups, the very effect being sought in the study.

Table 1: Education and Health Demographics by Age Group and CIND Status

	NCI		CIND-Single		CIND-Multiple	
Measure	Mid-Old	Old-Old	Mid-Old	Old-Old	Mid-Old	Old-Old
Years of Education	16.18 (2.86)	14.64 (2.89)	15.30 (3.14)	14.80 (3.04)	15.05 (2.85)	13.51 (3.33)
Absolute Health	4.37 (0.61)	4.31 (0.65)	4.22 (0.54)	4.12 (0.81)	4.10 (0.70)	3.97 (0.78)
Relative Health	4.55 (0.55)	4.52 (0.60)	4.43 (0.54)	4.41 (0.66)	4.49 (0.64)	4.31 (0.73)

Note. Standard deviations are in parentheses. On a 5-point scale (1 = very poor to 5 = very good), absolute health reflects self-rating of health relative to a perfect state with relative health reflecting self-reported health relative to same-aged peers. NCI = not cognitively impaired; CIND-Single = cognitive impairment in one domain; CIND-Multiple = cognitive impairment in two or more domains.

Measures and Procedures

The Project MIND measurement battery consisted of multiple questionnaires and tasks focused on cognitive and non-cognitive variables. The test battery was administered during a group testing session, an individual intake session, and five individual testing sessions scheduled over a period of five to seven weeks. All participants completed the tasks in the same order. The group testing session took place at the University of Victoria, and the intake and testing sessions were completed in the participants' own homes.

Cognitive Tasks. Perceptual speed, reasoning, episodic memory, verbal fluency and vocabulary were the cognitive domains that were used to classify participants into the three groups (NCI, CIND-single, and CIND-multiple).

Perceptual speed. Perceptual processing speed was assessed using the Digit Symbol Substitution task (WAIS-R: Wechsler, 1981). Participants were presented with a coding key pairing nine numbers (1 through 9) with nine symbols. Printed under the coding key were rows of randomly ordered numbers with empty boxes below. Participants had 90 seconds to transcribe as many symbols as possible into the empty boxes based on the digit-symbol associations specified in the coding key. The number of correctly completed items represented the outcome measure.

Reasoning. Inductive reasoning was assessed using the Letter Series test (Thurstone, 1962). Participants were presented with a string of letters forming a distinct pattern. The task required the participant to inductively decipher the pattern in the target string and provide the next letter in the string congruent with the pattern presented. Total number correct out of 20 patterns comprised the outcome measure.

Episodic memory. The word recall task consisted of immediate free recall of two lists of 30 English words selected from the total set of six lists (Hultsch, Hertzog, & Dixon, 1990). Each list consisted of six words from each of five taxonomic categories (e.g., birds, flowers) typed on a single page in unblocked order. Participants had two minutes to study each list and five minutes to write their recall. The number of correctly recalled words averaged across the two lists made up the outcome measure.

Verbal fluency. Each participant's verbal fluency was assessed using the Controlled Associations test from the Educational Testing Service (ETS) kit of factor-referenced cognitive tests (Ekstrom, French, Harman, & Dermen, 1976). The test required the generation of as many synonyms as possible in response to a set of target words. Participants had six minutes to complete the test with the total number of correct synonyms representing the fluency score.

Vocabulary. Crystallized ability was measured using a recognition vocabulary test. The 54-item multiple-choice test was composed by concatenating three 18-item tests from the ETS kit of factor-referenced cognitive tests (Ekstrom et al., 1976). Participants were given 15 minutes with the total number of correct items representing the vocabulary score.

Reaction Time (RT) Tasks

The principal measures of interest were three multi-trial computer-based RT tasks. All three measures assessed speed of responding to relatively simple non-verbal signals. Tasks were administered on laptop computers and measures of latency (in milliseconds) were obtained.

Simple reaction time (SRT). For SRT, the participants were presented with a warning stimulus (plus sign) followed by a signal stimulus (box) in the middle of the screen. Participants were instructed to press a key with their preferred hand as quickly as possible when the signal stimulus appeared. A total of 10 practice trials followed by 50 test trials were administered. Ten randomly arranged trials were presented at each of 5 intervals separating the warning and signal stimulus (500, 625, 750, 875, and 1000 ms). The latencies of the 50 trials comprised the SRT measure to be used in the analysis.

Choice reaction time (CRT). For CRT, the participants received a warning stimulus consisting of a horizontal row of four plus signs on the screen. The response keyboard had four keys in a horizontal array corresponding to the display on the screen. After a delay of 1000 ms, one of the plus signs changed into a box. The location of the box was randomly equalized across trials. Participants were instructed to press the key corresponding to the location of the box as quickly as possible. Although the instructions emphasized speed, participants were also instructed to minimize errors. A total of 10 practice trials followed by 60 test trials were administered. The latencies of the 60 trials comprised the CRT measure to be used in the analysis.

Choice reaction time 1-back (BRT). For BRT, the stimulus display and response keyboard were the same as for the CRT (4 choice) task. For the BRT task, participants were instructed to press the key corresponding to the location of the box on the previous trial as quickly as possible. Although the instructions emphasized speed, participants were also instructed to minimize errors. A total of 10 practice trials and 61 test trials were administered. Because participants made no response on Trial 1, the latencies of the remaining 60 test trials were used for analysis.

Data Preparation

The distributions of raw latency scores from the RT tasks were examined for outliers. Extremely fast or slow responses could be due to errors (e.g. participant distraction, accidental key press, etc.). Hultsch et al. (2000) note that removal of any outliers will reduce the intraindividual variability and therefore this strategy represents a conservative approach for detecting group differences. A trimming procedure based on that used by Hultsch et al. (2000) was used for this purpose. A lower bound for legitimate responses was set for each task and individual trial scores below this limit were dropped. The limits used were: SRT = 150ms, CRT = 150ms and BRT = 150ms. Computing the mean and standard deviation separately for each of the three groups and dropping any trials exceeding the mean by 3+ SD established the upper bound of legitimate responses. The number of trials dropped across the entire Persons x Trials data matrix was relatively small given the number of data points involved (SRT = 1.7%; CRT = 2.8%; BRT = 3.4%). Any missing values were imputed using a regression procedure in which missing value estimates are based on the relationships among responses across trials.

CHAPTER 3

Results

Data were analyzed in four parts. The first set of analyses examined the differences in accuracy as a function of age and group. While the focus of the present study was the latency scores, it was expected that significant differences in overall accuracy would be observed as a function of age, CIND and their interaction. The second set of analyses examined average level of performance as a function of age, group, and occasion. Although the interest of the study was intraindividual variability, it was expected that significant differences in overall level of performance would be observed as a function of age, group, occasion and their interactions. As well, establishment of significant differences in overall level of performance due to age, group, occasion and their interactions lends credence to purifying the data for the analyses of interest. The third set of analyses focused on the effects of age, group, occasion and their interaction on intraindividual variability. The fourth set of analyses focused on the intercorrelations between (a) measures of intraindividual variability and (b) measures of intraindividual variability and level of performance.

Accuracy Analysis. Separate 2 (Age) X 3 (CIND) ANOVAs were computed on the percent accuracy scores for the CRT and BRT task (the SRT task does not provide accuracy information).

The overall accuracy for the CRT task was 97.8%. The ANOVA results revealed significant main effects associated with Age, $\underline{F}$ (1, 299) = 5.84, $\underline{p} < .02$, $\underline{\eta}^2 = .02$, with individuals in the OO group being less accurate ($\underline{M}$ = 96.4%) than the MO group ($\underline{M}$ =

98.8%). The effect of CIND status was not significant ($p = .19$). As well, the interaction between Age and CIND status was not significant ($p = .15$).

The overall accuracy for the BRT task was 89.2%. The ANOVA results revealed significant main effects associated with Age, F (1, 299) = 70.62, $p < .00$, $\eta^2 = .19$ and CIND status, F (2, 299) = 26.08, $p < .00$, $\eta^2 = .15$. The Age X CIND interaction was also significant, F (1, 299) = 5.02, $p < .00$, $\eta^2 = .03$. Pairwise comparisons within Age group revealed that for MO individuals, accuracy was significantly lower in the CIND-multiple group ($M = 88.7\%$) than the NCI ($M = 94.4\%$) and CIND-single groups ($M = 94.0\%$). For OO individuals, accuracy was significantly lower in the CIND-multiple ($M = 77.1\%$) and CIND-single ($M = 83.2\%$) groups than in the NCI group ($M = 89.8\%$).

Performance Level Analysis. A 2 (Age) x 3 (CIND) x 5 (Occasions) MANOVA computed on the raw latency scores for the three RT tasks revealed significant omnibus effects associated with Age, Wilks' $\lambda = .891$, F (3, 91468) = 3740.503, $p < .001$, $\eta^2 = .11$, CIND status, Wilks' $\lambda = .906$, F (6, 182936) = 1546.656, $p < .001$, $\eta^2 = .05$ and Occasion, Wilks' $\lambda = .907$, F (12, 242001.9) = 754.10, $p < .001$, $\eta^2 = .03$. The Age X CIND interaction was also significant, Wilk's $\lambda = .983$, F (6, 182936) = 262.01, $p < .001$, $\eta^2 = .01$, as was the Occasion X Age interaction, Wilks' $\lambda = .996$, F (12, 242001.9) = 27.04, $p < .001$, $\eta^2 = .001$ and the Occasion X CIND status interaction, Wilks' $\lambda = .997$, F (24, 265285.6) = 12.03, $p < .001$, $\eta^2 = .001$. The three way Age X CIND X Occasion interaction was also significant, Wilks' $\lambda = .998$, F (24, 265285.6) = 8.07, $p < .001$, $\eta^2 = .001$.

Univariate ANOVAs indicated there were significant age group differences for SRT: F (1, 91470) = 3329.51, $p < .001$, $\eta^2 = .04$; CRT: F (1, 91470) = 3392.811, $p <$

.001, η^2 = .04 and BRT: F (1, 91470) = 6971.00, p < .001, η^2 = .07. CIND status differences were also observed for SRT: F (2, 91470) = 711.14, p < .001, η^2 = .02; CRT, F (2, 91470) = 1213.15, p < .001, η^2 = .03, and BRT, F (2, 91470) = 3644.41, p < .001, η^2 = .07. Significant occasion differences were observed for SRT, F (4, 91470) = 11.07, p < .001, η^2 = .0001, for CRT, F (4, 91470) = 380.27, p < .001, η^2 = .02, and for BRT, F (4, 91470) = 2141.21, p < .001, η^2 = .09. Table 5 shows the means for main effects of Age and CIND status.

The interaction between Age and CIND status was significant for SRT, F (2, 91470) = 29.44, p < .001, η^2 = .0002, for CRT, F (2, 91470) = 53.88, p < .001, η^2 = .001, and for BRT, F (2, 91470) = 736.30, p < .001, η^2 = .02. The interaction between Occasion and Age was significant for SRT, F (4, 91470) = 11.26, p < .001, η^2 = .0001, for CRT, F (4, 91470) = 22.76, p < .001, η^2 = .001, and BRT, F (4, 91470) = 55.92, p < .001, η^2 = .002. The interaction between Occasion and CIND status was significant for SRT, F (8, 91470) = 2.64, p < .01, η^2 = .0001, for CRT, F (8, 91470) = 2.69, p < .01, η^2 = .0001 and for BRT, F (8, 91470) = 31.93, p < .001, η^2 = .003.

The three-way interaction between Age, Occasion and CIND status was significant for SRT, F (8, 91470) = 5.64, p < .001, η^2 = .0002, CRT, F (8, 91470) = 5.88, p < .001, η^2 = .001, and for BRT, F (8, 91470) = 13.23, p < .001, η^2 = .001. Table 3 presents within age-group means for the three RT tasks by CIND status and occasion. Pairwise comparisons within age groups revealed that across all three tasks, OO individuals for all three categories of CIND status were slower than MO individuals as expected. For all individuals in the NCI and the CIND-single groups and MO individuals in the CIND-multiple group, practice effects were noticeable on CRT and BRT with

individuals' latency on these tasks decreasing after the first occasion. Practice effects were not observed for SRT in these groups. However, for the OO CIND-multiple group, after the first occasion for SRT latency decreased, indicating that for this group, practice effects were present.

Table 2: Latency Means by Age Group and CIND Status

Measure	Middle-Old	Old-Old	NCI	CIND-Single	CIND-Multiple
Simple RT	351.14 (111.39)	398.84 (133.20)	356.40 (111.56)	377.22 (120.01)	393.68 (142.66)
Choice RT	566.73 (140.10)	623.74 (161.51)	567.69 (142.31)	598.54 (151.38)	625.91 (163.28)
Choice RT 1-back	1100.94 (769.59	1543.86 (1047.37)	1107.32 (718.03)	1238.92 (843.73)	1684.03 (1187.92)

Note. NCI = not cognitively impaired; CIND-Single = cognitive impairment in one domain; CIND-Multiple = cognitive impairment in two or more domains. SD in parentheses.

Table 3: Latency Means Within Age Group, by CIND Status and Occasion

Middle Old

Measure	NCI Occasion				
	1	2	3	4	5
Simple RT	335.61	339.29	337.48	332.17	332.32
	(110.45)	(98.15)	(96.14)	(91.47)	(94.72)
Choice RT	577.13	553.41	535.80	537.39	533.11
	(155.77)	(124.96)	(121.67)	(115.01)	(114.97)
Choice RT 1-back	1392.96	1069.61	951.43	865.49	803.52
	(858.37)	(646.43)	(595.58)	(532.92)	(492.25)
	CIND-Single				
	1	2	3	4	5
Simple RT	366.10	362.38	364.32	361.32	354.09
	(121.76)	(113.86)	(113.65)	(108.78)	(111.04)
Choice RT	594.35	577.22	573.14	566.07	548.05
	(161.70)	(145.44)	(132.92)	(137.45)	(127.07)
Choice RT 1-back	1380.10	1139.65	966.13	879.88	805.66
	(891.69)	(743.16)	(600.72)	(570.73)	(536.04)
	CIND-Multiple				
	1	2	3	4	5
Simple RT	363.27	369.68	369.20	361.69	367.27
	(149.85)	(119.31)	(117.18)	(117.96)	(120.90)
Choice RT	625.66	596.40	586.65	586.60	582.29
	(183.84)	(149.21)	(140.46)	(140.42)	(135.80)
Choice RT 1-back	1809.41	1392.76	1255.57	1163.88	1093.58
	(1211.17)	(899.10)	(843.81)	(769.04)	(733.02)

Table Continues

Old-Old

Measure	NCI Occasion				
	1	2	3	4	5
Simple RT	387.29 (138.73)	374.75 (116.84)	386.86 (116.33)	380.68 (112.47)	381.71 (118.12)
Choice RT	627.11 (176.24)	601.86 (159.74)	583.95 (145.76)	578.19 (137.01)	572.29 (141.97)
Choice RT 1-back	1603.37 (931.36)	1305.35 (774.98)	1165.59 (689.66)	1038.00 (596.56)	981.99 (565.18)
	CIND-Single				
	1	2	3	4	5
Simple RT	402.67 (144.17)	396.06 (119.84)	409.59 (120.78)	396.35 (114.39)	401.96 (123.48)
Choice RT	691.74 (196.46)	642.67 (156.02)	631.78 (138.33)	612.43 (134.37)	620.60 (131.66)
Choice RT 1-back	2101.40 (1152.78)	1622.11 (888.09)	1499.96 (835.57)	1328.76 (756.13)	1221.03 (684.20)
	CIND-Multiple				
	1	2	3	4	5
Simple RT	440.05 (226.84)	415.85 (131.15)	414.59 (128.83)	418.45 (132.75)	423.75 (119.72)
Choice RT	702.63 (211.15)	666.77 (167.75)	647.05 (148.66)	635.82 (149.48)	637.00 (148.96)
Choice RT 1-back	2744.33 (1770.29)	2089.72 (1246.87)	1988.49 (1119.97)	1725.02 (997.02)	1665.02 (938.34)

Note. NCI = not cognitively impaired; CIND-Single = cognitive impairment in one domain; CIND-Multiple = cognitive impairment in two or more domains. SD in parentheses.

IIV Analysis. For the next three parts of the statistical analysis, the data were purified to remove any systematic effects. Because the interest of this study is intraindividual variability, any age-related or group-related differences in speed of performance on all tasks will affect the indices of variability, and thus present as a potential confound for the analysis of intraindividual variability. To address these issues, the trial and group main effects and their potential interactions were partialled out of the data by regressing each dependent measure on these variables. This produced residual scores which are uncontaminated by group differences in speed of accuracy of performance. Additionally, this procedure removed any systematic variability across trials due to practice and learning to learn effects. These residual scores were then converted to T scores to provide a common metric for comparing results across tasks.

Using these purified T scores, intraindividual standard deviations (ISDs) were calculated as measures of intraindividual variability. The ISDs indicate how much an individual deviated from his/her own performance (Fuentes et al., 2001). Higher ISD scores indicate relatively inconsistent performance across trials, whereas lower scores indicate relatively consistent performance.

A 2 (Age) x 3 (CIND) x 5 (Occasions) MANOVA computed on the ISD scores for the three RT tasks revealed significant omnibus effects associated with Age, Wilks' $\lambda = .804$, $F\ (3, 1493) = 121.10$, $p < .001$, $\eta^2 = .20$, CIND status, Wilks' $\lambda = .705$, $F\ (6, 2986) = 95.15$, $p < .001$, $\eta^2 = .16$ and Occasion, Wilks' $\lambda = .978$, $F\ (12, 3950.398) = 2.83$, $p < .001$, $\eta^2 = .01$. The Age X CIND interaction was also significant, Wilk's $\lambda = .943$, $F\ (6, 2986) = 14.80$, $p < .001$, $\eta^2 = .03$, as was the Occasion X Age interaction, Wilks' $\lambda = .985$, $F\ (12, 3950.398) = 1.91$, $p < .05$, $\eta^2 = .01$ and the Occasion X CIND status

interaction, Wilks' $\lambda = .959$, F (24, 4330.755) = 2.645, $p < .001$, $\eta^2 = .01$. The three-way interaction was not significant.

Univariate ANOVAs indicated there were significant age group differences for SRT: F (1, 1495) = 75.91, $p < .001$, $\eta^2 = .05$; CRT: F (1, 1495) = 140.85, $p < .001$, $\eta^2 = .09$ and BRT: F (1, 1495) = 272.95, $p < .001$, $\eta^2 = .15$. For all tasks, OO ($M_{SRT} = 7.91$, $M_{CRT} = 8.62$, $M_{BRT} = 9.17$) were more variable than MO individuals ($M_{SRT} = 6.71$, $M_{CRT} = 7.42$, $M_{BRT} = 6.82$).

CIND status differences were also observed for SRT: F (2, 1495) = 56.06, $p < .001$, $\eta^2 = .07$; CRT, F (2, 1495) = 40.48, $p < .001$, $\eta^2 = .05$, and BRT, F (2, 1495) = 286.47, $p < .001$, $\eta^2 = .28$. For CRT, the CIND-multiple group ($M_{ISD} = 8.53$) was more inconsistent than the CIND-single group ($M_{ISD} = 7.89$), which was again more variable than the NCI group ($M_{ISD} = 7.42$). Significant occasion differences were observed for SRT F (4, 1495) = 7.21, $p < .001$, $\eta^2 = .02$. The first occasion was more variable ($M_{O1} = 7.88$) than all other occasions ($M_{O2} = 7.57$, $M_{O3} = 7.23$, $M_{O4} = 6.91$, $M_{O5} = 6.95$). The effect of occasion was not significant for CRT, F (4, 1495) = 2.26, $p = .06$, $\eta^2 = .01$ or BRT, F (4, 1495) = 0.55, $p = .70$, $\eta^2 = .001$.

Table 4 presents the mean ISDs on the three RT tasks by age and CIND group. The interaction between Age and CIND status was significant for SRT, F (2, 1524) = 10.34, $p < .001$, $\eta^2 = .01$ and for BRT, F (2, 1524) = 35.93, $p < .001$, $\eta^2 = .05$, but not for CRT, F (2, 1524) = .287, $p > .10$. Pairwise comparisons within age groups revealed that for the SRT task, in the MO group, those with CIND-multiple were more variable than those with CIND-single and NCI (CIND-multiple $M_{ISD} = 7.23$; CIND-single $M_{ISD} = 6.77$, $p < .03$; NCI $M_{ISD} = 6.11$, $p < .001$) and the CIND-single group was more variable than

NCI group ($p < .001$). For the OO group on the SRT task, the CIND-multiple group was much more variable than the CIND-single and NCI groups (CIND-multiple $M_{ISD} = 9.37$; CIND-single $M_{ISD} = 7.36$, $p < .001$; NCI $M_{ISD} = 7.01$) but the CIND-single group was not significantly different from the NCI group ($p > .10$). For the BRT task, in the MO group, those with CIND-multiple were more variable than those with CIND-single and NCI (CIND-multiple $M_{ISD} = 8.49$; CIND-single $M_{ISD} = 6.15$, $p < .03$; NCI $M_{ISD} = 5.82$, $p < .001$) but the CIND-single group was not significantly different than the NCI group ($p > .10$). For the OO group on the BRT task, the CIND-multiple group was much more variable than the CIND-single and the NCI groups (CIND-multiple $M_{ISD} = 12.08$; CIND-single $M_{ISD} = 8.78$, $p < .001$; NCI $M_{ISD} = 6.66$, $p < .001$) and the CIND-single group was much more variable than the NCI group ($p < .001$). Figure 1, 2, and 3 present the mean ISDs for the three RT tasks by Age and CIND status.

The interaction between Age and Occasion was significant for SRT, $F (4, 1524) = 4.79$, $p < .001$, $\eta^2 = .01$, but not for CRT or BRT. Pairwise comparisons for SRT within age groups revealed that in the MO group, variability was not significantly different across any of the occasions, $p > .05$. For the OO group, participants were more variable on the first occasion ($M_{ISD} = 8.81$) than for any other occasion (2^{nd} $M_{ISD} = 7.96$, $p < .05$; 3^{rd} $M_{ISD} = 7.68$, $p < .001$; 4^{th} $M_{ISD} = 7.18$, $p < .001$; 5^{th} $M_{ISD} = 7.27$, $p < .001$) and the second occasion was significantly more variable than the fourth ($p < .01$). The other occasions did not significantly differ from each other, $p > .05$.

The interaction between Cognitive Status and Occasion was significant for SRT, $F (8, 1524) = 7.25$, $p < .001$, $\eta^2 = .04$, but not for CRT or BRT. Pairwise comparisons for SRT within Cognitive Status revealed that those in the NIC group were more variable

on the second occasion (2nd $\underline{M}_{ISD}$ = 6.92) than the fourth occasion (4th $\underline{M}_{ISD}$ = 6.25) ($p<.05$). The MCI-mild group showed less variability on the first occasion (1st $\underline{M}_{ISD}$ = 6.66) than the second (2nd $\underline{M}_{ISD}$ = 7.57) ($p<.05$) and more on the second that the fourth (4th $\underline{M}_{ISD}$ = 6.62) ($p<.05$). For the MCI-moderate group, the first occasion ($\underline{M}_{ISD}$ = 10.33) was more variable than the other occasions, which did not differ from each other (2nd $\underline{M}_{ISD}$ = 8.13, $\underline{p} < .001$; 3rd $\underline{M}_{ISD}$ = 7.88, $\underline{p} < .001$; 4th $\underline{M}_{ISD}$ = 7.77; $\underline{p} < .001$; 5th $\underline{M}_{ISD}$ = 7.25, $\underline{p} < .001$).

In order to determine the effect of task complexity a profile analysis was run via a 2(Age) X 3(CIND Status) X 3(Task) Repeated Measures MANOVA. Significant TASK differences were observed, Greenhouse-Geisser $\underline{F}$ (1.918, 2913.008) = 47.23, $\underline{p} < .001$, $\underline{\eta}^2 = .03$. Significant TASK X AGE, Greenhouse-Geisser $\underline{F}$ (1.918, 2913.008) = 32.12, $\underline{p} < .001$, $\underline{\eta}^2 = .02$ and TASK X CIND, Greenhouse-Geisser $\underline{F}$ (3.835, 2913.008) = 64.14, $\underline{p} < .001$, $\underline{\eta}^2 = .08$, interactions were also observed.

The three-way interaction between TASK X AGE X CIND Status was significant, Greenhouse-Geisser $\underline{F}$ (3.835, 2913.008) = 15.594, $\underline{p} < .001$, $\underline{\eta}^2 = .02$. Within-age and CIND status, pairwise comparisons revealed that MO-NCI individuals were more variable on CRT ($\underline{M}$ = 6.93) than SRT ($\underline{M}$ = 6.11) ($\underline{p} < .001$) and BRT ($\underline{M}$ = 5.82) ($\underline{p} < .001$) and were more variable on SRT than BRT ($\underline{p} = .04$). The MO-CIND Single individuals were also more variable on CRT ($\underline{M}$ = 7.39) than SRT ($\underline{M}$ = 6.77) ($\underline{p} < .001$) and BRT ($\underline{M}$ = 6.15) ($\underline{p} < .001$) and were more variable on SRT than BRT ($\underline{p} < .001$). The MO-CIND Multiple individuals, however, showed a different pattern of results. These individuals were more variable on BRT ($\underline{M}$ = 8.49) than SRT ($\underline{M}$ = 7.23) ($\underline{p} < .001$) and CRT ($\underline{M}$ = 7.93) ($\underline{p} < .001$) and were more variable on CRT than SRT ($\underline{p} < .001$). In the

OO group, NCI individuals showed a pattern of results similar to that of the MO group, showing greater variability on CRT (M = 8.03) than SRT (M = 7.01) ($p < .001$) and BRT (M = 6.66) ($p < .001$) and on SRT than BRT ($p = .02$). The OO-CIND Single group was more variable on BRT (M = 8.78) than SRT (M = 7.36) ($p < .001$) but was not more variable on BRT than CRT (M = 8.65) ($p = .54$). Further, these individuals were more variable on CRT than SRT ($p < .001$). The OO-CIND Multiple group was more variable on BRT (M = 12.08) than CRT (M = 9.17) ($p < .001$) and SRT (M = 9.37) ($p < .001$). Performance on CRT and SRT was not significantly different for this group ($p = 52$). Figures 6 and 7 show the ISD scores by task, age and CIND status.

In order to determine which tasks best differentiated the groups, a 3 (TASK) X 6 (GROUP) MANOVA was run. Pairwise comparisons within each task revealed than on SRT, MO-NCI individuals were less variable that all other groups ($p < .001$). MO-CIND Single individuals were not significantly different from MO-CIND Multiple or OO-NCI individuals ($p > .05$). MO-CIND Multiple individuals were also not significantly different from OO-NCI and OO-CIND Single individuals on this task ($p > 05$). OO-CIND Single individuals were also not significantly different from OO-NCI individuals ($p > .05$). OO-CIND Multiple individuals were more variable than all other groups on this task ($p < .001$).

On CRT, MO-NCI individuals were again less variable than all other groups($p < .001$). MO-CIND Single individuals were more variable than MO-NCI individuals ($p < .001$) but less variable than all other groups ($p < .001$). MO-CIND Multiple individuals were similar to OO-NCI individuals on this task ($p > .05$) and both groups were less variable than OO-CIND Single and OO-CIND Multiple individuals ($p < .001$). OO-

CIND Single and OO-CIND Multiple were more variable than all other groups and OO-CIND Multiple was the most variable group on this task ($p < .001$).

On BRT, MO-NCI and MO-CIND Single individuals performed similarly ($p > .05$) and both were less variable than all other groups ($p < .001$). Of note, MO-CIND Multiple individuals were similar to OO-CIND Single individuals ($p > .05$) and both groups were more variable than OO-NCI individuals but less variable than OO-CIND Multiple individuals ($p < .001$). OO-CIND Multiple individuals were more variable than all other groups ($p < .001$).

Table 4: Intraindividual Standard Deviations (ISDs) by Age Group and CIND Status

	NCI		CIND-Single		CIND-Multiple	
Measure	Mid-Old	Old-Old	Mid-Old	Old-Old	Mid-Old	Old-Old
Simple RT	6.11	7.01	6.77	7.36	7.23	9.37
Choice RT	6.93	8.03	7.39	8.65	7.93	9.17
Choice RT 1-back	5.82	6.66	6.15	8.78	8.49	12.08

Note. NCI = not cognitively impaired; CIND-Single = cognitive impairment in one domain; CIND-Multiple = cognitive impairment in two or more domains.

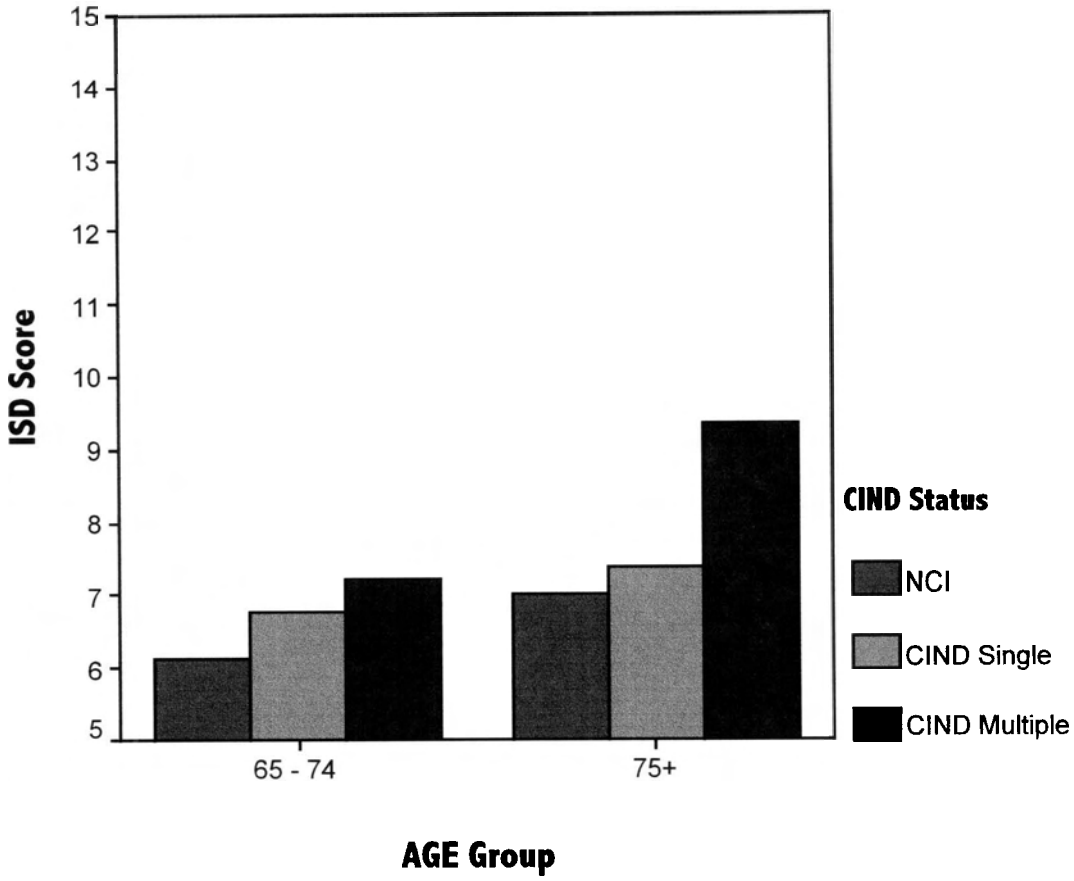

Figure 1. Mean intraindividual standard deviation (ISD) scores on simple reaction time as a function of age group and CIND status.

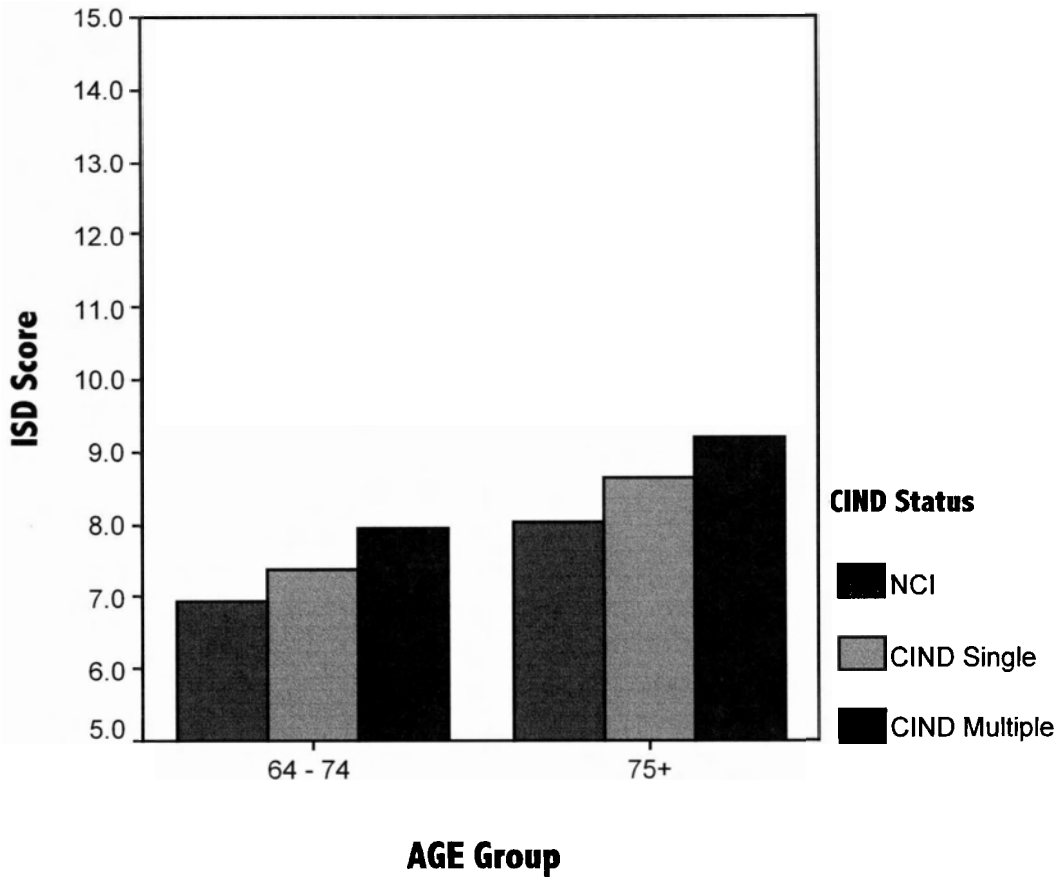

Figure 2: Mean ISD scores on choice reaction time task as a function of age group and CIND status.

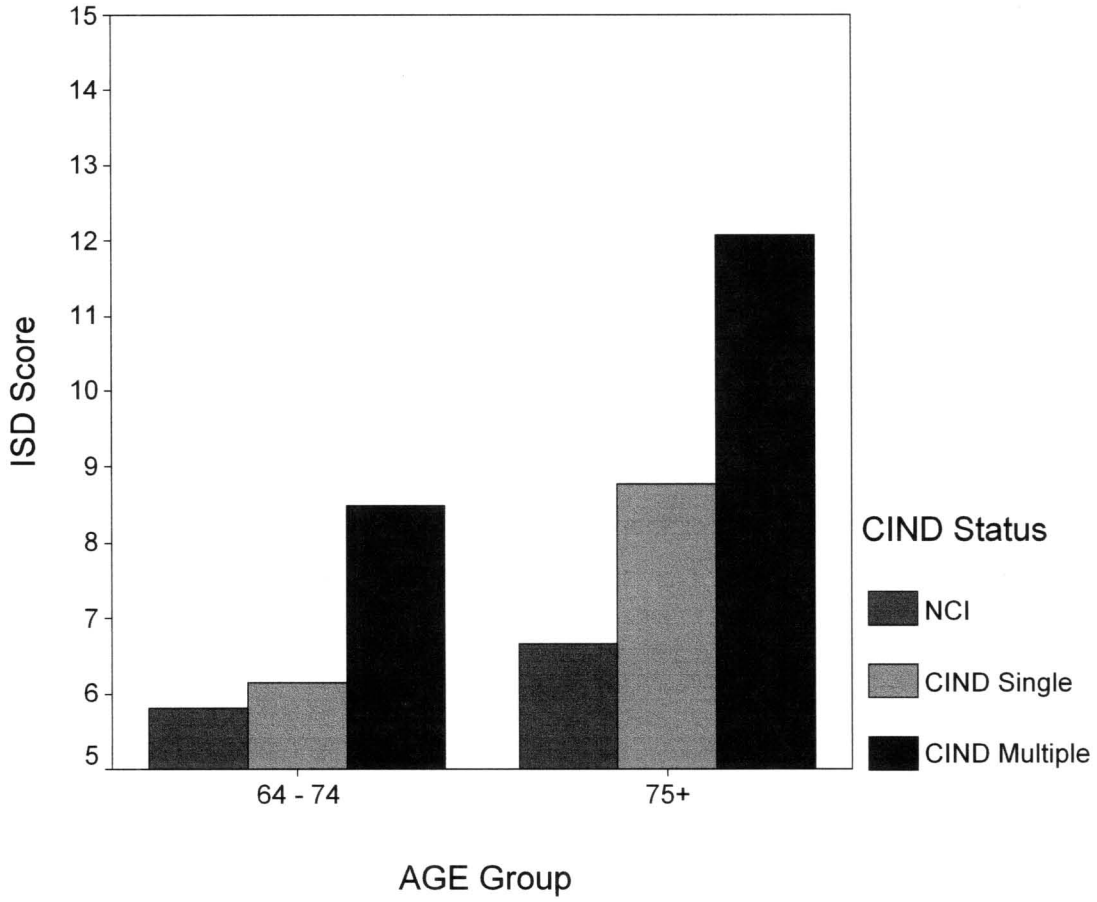

Figure 3: Mean ISD scores on choice reaction time 1- back task as a function of age group and CIND status.

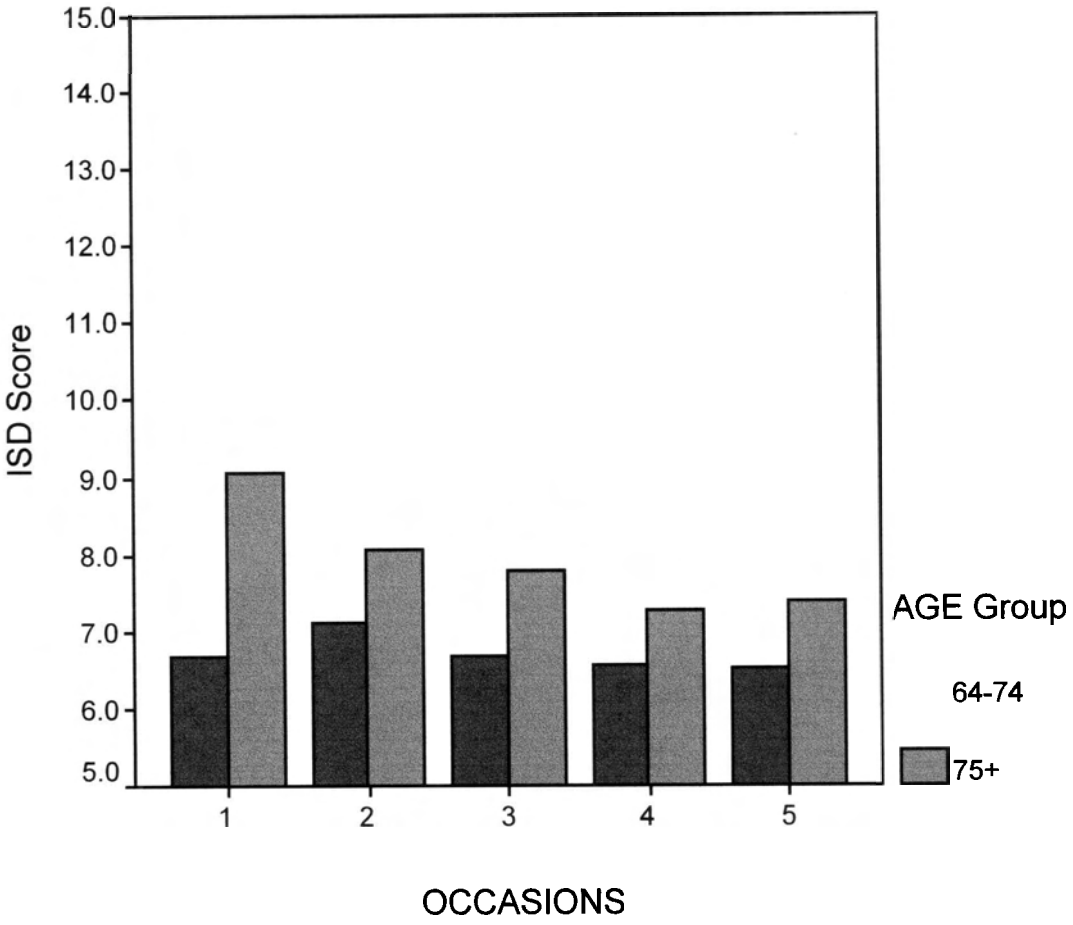

Figure 4: Mean ISDs on simple reaction time task by occasion and age group.

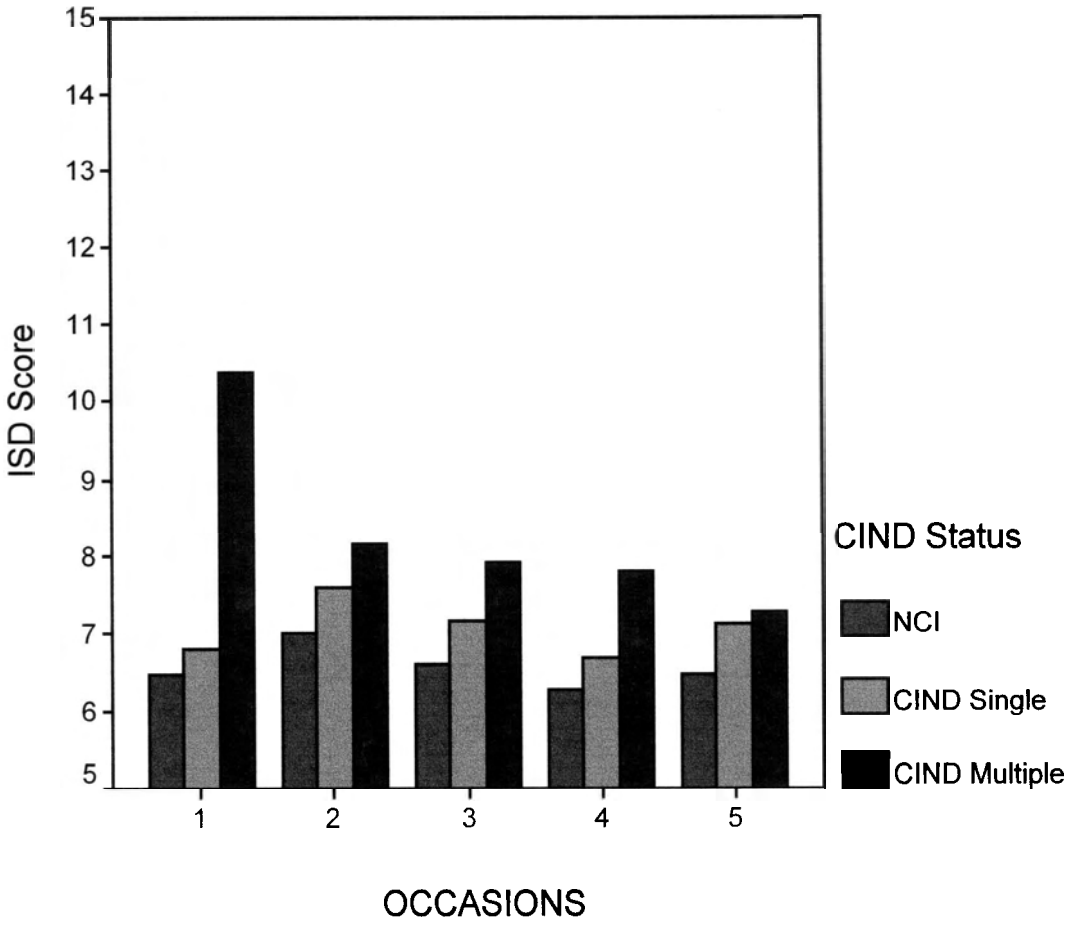

Figure 5: Mean ISDs for simple reaction time task by occasion and CIND status.

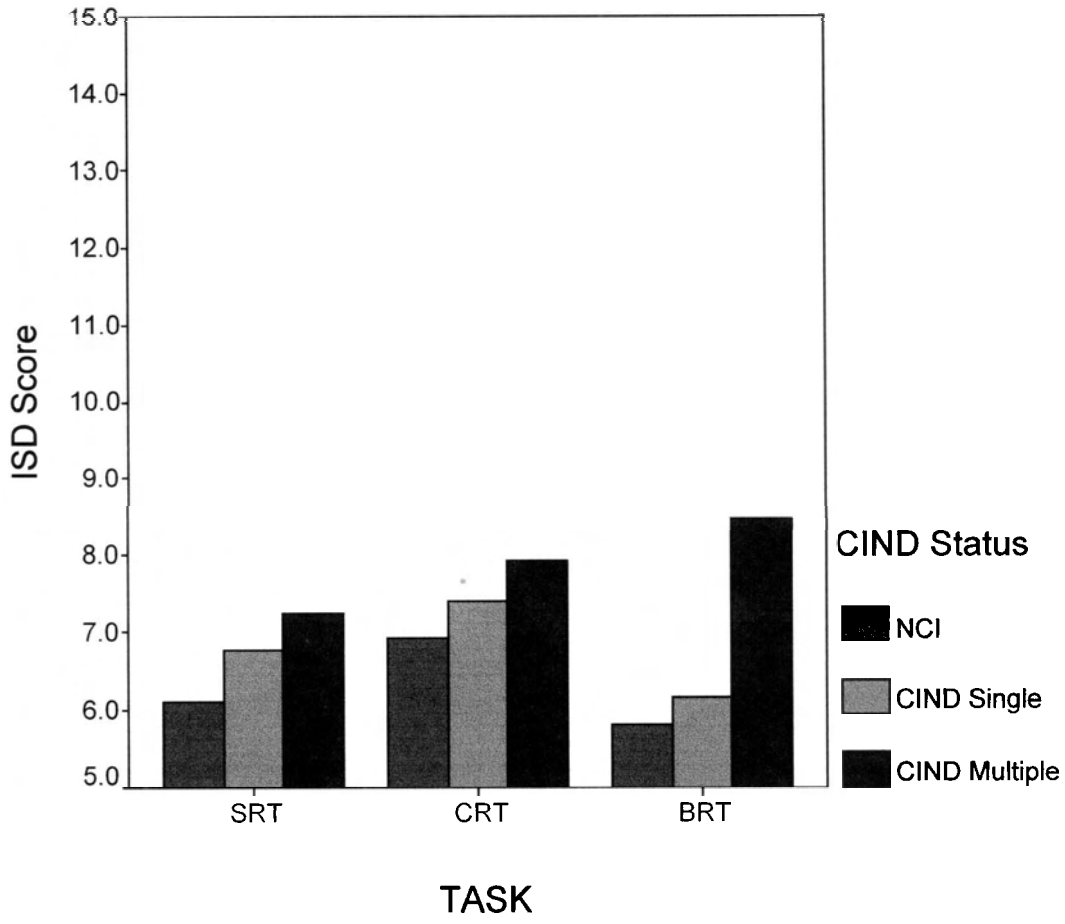

Figure 6. Mean ISDs by task and CIND status for mid-old individuals.

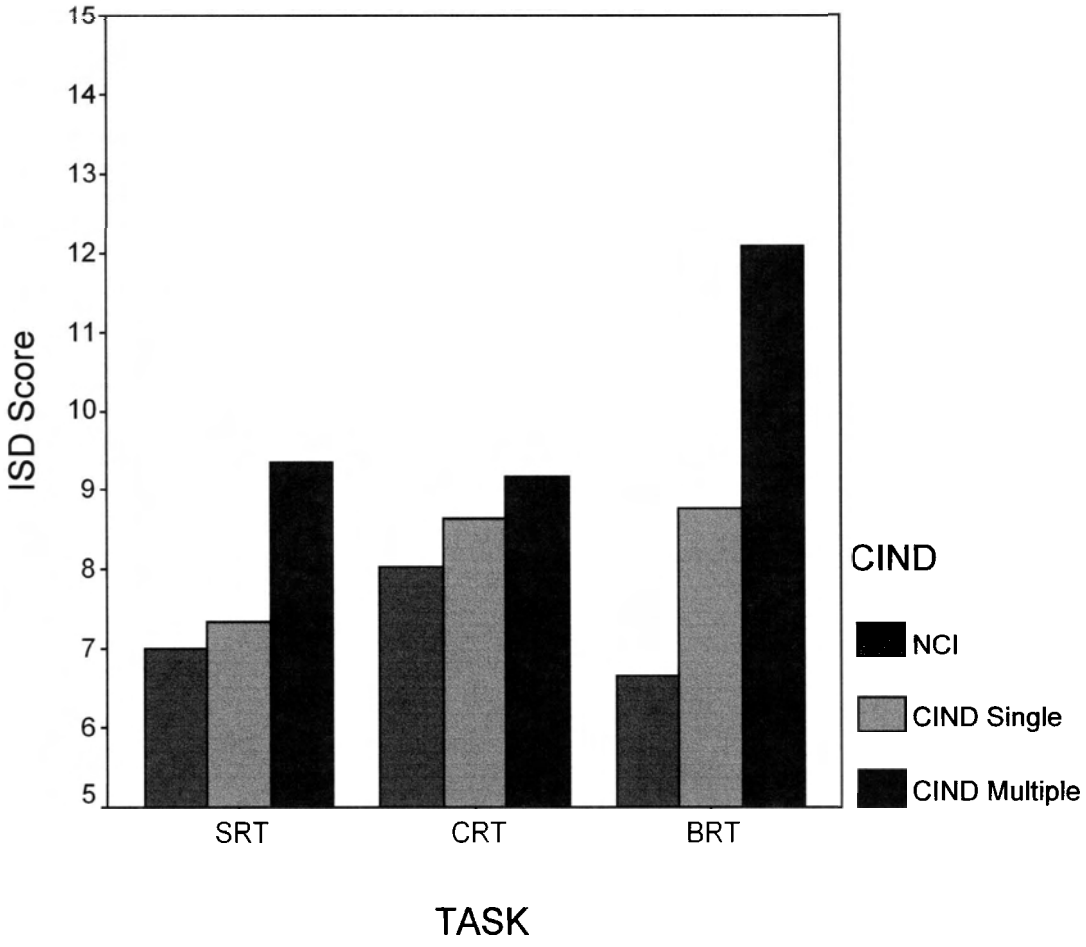

Figure 7. Mean ISDs by task and CIND status for old-old individuals.

Correlational Analyses. To examine the relationship among indicators of intraindividual variability, a series of correlational analyses were run on the ISDs of the three RT tasks. Relative stability in individual differences in intraindividual variability was observed. Table 5 shows the intercorrelations of the average across-trial latency ISDs for each of the three tasks. All of the correlations are significant at $p < .01$, which indicates that individuals who were more variable on one task were more variable on the other two tasks.

The relationship of indicators of intraindividual variability and overall level of performance was also examined. Table 6 shows correlations of average across-trial ISDs for all three RT tasks and overall level of performance as shown by mean latency for all three RT tasks. As prior research has found, it was observed that greater intraindividual variability on all tasks was related to slower overall performance.

Table 5: Intercorrelations Among Measures of Intraindividual Variability

Measure	1.	2.	3.
1. SRT ISD	___		
2. CRT ISD	.425**	___	
3. BRT ISD	.499**	.490**	___

Note: ISD = Intraindividual standard deviation; SRT = simple reaction-time task; CRT = four-choice reaction time task; BRT = 1-back four-choice reaction time task.

** $p < .01$.

Table 6: Correlations of Measures of Intraindividual Variability with Level of Performance.

ISD Measure	Level of Performance		
	SRT	CRT	BRT
SRT	.365**	.419**	.476**
CRT	.205**	.479**	.453**
BRT	.356**	.525**	.860**

Note: ISD = Intraindividual standard deviation; SRT = simple reaction time task; CRT = four-choice reaction time task; BRT = 1-back four-choice reaction time task.

** $p < .01$.

CHAPTER 4

Discussion

The usual approach to studying mild cognitive impairment has compared measures of average performance levels at one time with subsequent performance levels at another time. While this approach has provided a great deal of information in the area, the inconsistency of the results suggest that perhaps average performance is not sensitive enough for impairment of this mild nature (for review, see Palmer et al., 2003). Thus, the present study sought to investigate an alternative approach to studying mild cognitive impairment, intraindividual variability.

Prior research had indicated that intraindividual variability was higher in persons with neurological disturbance (Fuentes et al., 2001; Hultsch et al., 2000; Hultsch et al., 2002; Lawton et al., 1996; Li & Lindenberger, 1999; Li et al., 2001; Murtha et al., 2002, Strauss et al., 2000). As such, intraindividual variability in cognitive performance has potential as a method for identifying individuals with cognitive impairments too mild to be detected with typical diagnostic tools.

The goals of the study were to answer six main questions concerning intraindividual inconsistency in this population. The first of these questions concerned whether intraindividual variability could discriminate between healthy individuals and those with mild cognitive impairment. In order for intraindividual variability to be useful as an early detection method, it must be at minimum able to discriminate at this level. The results are supportive of previous findings that intraindividual variability is higher in individuals with suggested neurological compromise (Fuentes et al., 2001; Hultsch et al., 2000; Hultsch et al., 2002; Lawton et al., 1996; Li & Lindenberger, 1999; Li et al., 2001;

Murtha et al., 2002; Strauss et al., 2000). Individuals with mild impairment were more variable than neurologically healthy individuals.

The second question pertained to the sensitivity of intraindividual variability in discriminating mild cognitive impairment in one domain versus in multiple domains. The results of the present study support prior research indicating that individuals with more severe impairment showed greater intraindividual variability than those with less impairment (Stuss et al., 1989). This finding, in addition to the first, provides support to prior theory that intraindividual variability is an indicator of neurobiological function (Li & Lindenberger, 1999).

The third question pursued by this study was the relationship of intraindividual variability with overall level of performance in individuals with mild cognitive impairment. It was expected that overall performance would be impacted by the same neurobiological status as the variability and as such, higher variability would be related to lower overall performance as prior research had found with other populations (Burton et al., 2002; Hultsch et al., 2000). This hypothesis was supported by the results. Individuals, who were more variable on the reaction time tasks, had slower latency on the same as well as other tasks.

The intrinsic nature of intraindividual variability was the focus of our fourth question. If intraindividual variability is reflective of neurobiological functioning, one would expect that different measures of intraindividual variability would be related to each other, such that individuals with high variability on one measure would also show high variability on another (Burton et al., 2002; Hultsch et al., 2000). The results support

this hypothesis, providing further evidence that intraindividual variability is intrinsic to the individual.

The fifth question assessed by this study concerned the complexity of the tasks. Prior research had found that with increasing task complexity, individuals with neurobiological dysfunction showed more variability in performance (Hultsch et al., 2000). In the present study, as the cognitive demands increased, in the mid-old group, only individuals with multiple domains of impairment showed the expected increase in variability with increasing demands of the task, with the most variability on BRT. Similarly, in the old-old group, only those with multiple domains of impairment showed greater inconsistency on the BRT task than the other tasks. However, the expected difference between CRT and SRT was not supported by this group's results. The results suggest that for individuals who have multiple domains of impairment, BRT is a more challenging task. However, for the other groups, it is unclear how task complexity impacts variability as three of the groups (MO-NCI, MO-CIND Single and OO-NCI) showed more variability on SRT than BRT, suggesting that for these groups, task complexity impacts inconsistency differently. Further research is needed to clarify these results.

The final question examined in the interaction of mild cognitive impairment and age on intraindividual variability. It was predicted that cognitive impairment would interact with age such that older individuals with more severe impairment would be the most variable group. This proved to be the case in this study on all the tasks. As well, older individuals with a single domain of impairment were similar overall to younger individuals with multiple domains of impairment on both SRT and BRT.

Overall, the results suggest that intraindividual variability is a marker for neurobiological dysfunction, even at the most mild stage of impairment. The results of this study suggest that intraindividual variability is sensitive enough to not only discriminate between healthy individuals and those with mild dysfunction but also between those with a single domain of mild dysfunction and those with multiple domains. This is an important finding for the area of mild cognitive impairment as this suggests that intraindividual variability has potential as a method of identifying those individuals who have the early signs of neurobiological dysfunction long before they appear dysfunctional on standard neuropsychological tests.

While the results of the present study are optimistic for early detection of mild cognitive changes, a few cautionary notes must be put forth. First, the population in this study was highly educated and thus, the generalizability of these results may be limited. It is suggested that in future studies of intraindividual variability, a population with a wide range of educational levels be used in order to improve on the generalizability of the results. Second, it is recommended that persons studying this phenomena use a multiple occasion approach as it was found that older individuals are more variable the first time they attempted a task than subsequent attempts. Third, for intraindividual variability to be used as a tool to determine for which individuals early medication is warranted, longitudinal studies of this phenomena's ability to predict progression to dementia must be conducted as potential consequences of medicating individuals who will not progress are unknown at this time. Finally, further research is needed to investigate the underlying neurobiological processes intraindividual variability represents. To date, the neurobiological basis of intraindividual variability is mere speculation.

In summary, intraindividual variability was found to discriminate between mild cognitive impairment and normal neurological functioning as well as between severities of mild cognitive impairment. Further, intraindividual variability was demonstrated as consistent across measures, positively related to task complexity and negatively related to overall level of performance. Intraindividual variability in cognitive performance is relevant to persons with mild cognitive impairment, not only as an indicator of overall performance levels but also as a potential marker for early treatment.

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