The Utility of Intraindividual Variability in Selective Attention Tasks as an Early Marker for Alzheimer’s Disease

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This study explored differences in intraindividual variability in 3 attention tasks across a large sample of healthy older adults and individuals with very mild dementia of the Alzheimer’s type (DAT). Three groups of participants (healthy young adults, healthy older adults, very mild DAT) were administered 3 experimental measures of attentional selection and switching (Stroop, Simon, task switching). The results indicated that a measure of intraindividual variability, coefficient of variation (CoV; $SD/M$), increased across age and early stage DAT. The CoV in Stroop discriminated the performance of 64 carriers from noncarriers in healthy older controls and the CoV in task switching was correlated with cerebrospinal fluid (CSF) biomarkers predictive of DAT.

Keywords: intraindividual variation, attention, aging, Alzheimer’s disease

There has been considerable interest in the ability to diagnose dementia of the Alzheimer type (DAT) in the earliest possible stage of the disease, thus discriminating healthy aging from early stage DAT. The elusive nature of the clinical detection of the early onset of DAT has been supported in longitudinal studies in presumed healthy older adults (e.g., Morris et al., 1996; Price & Morris, 1999; Rubin et al., 1998). These and other studies (e.g., Bennett et al., 2006) have indicated that the Alzheimer’s disease (AD) process may be present in the brain for years before the appearance of clinical symptoms. Thus, preclinical markers of the disease likely are present in some older individuals who appear to be clinically “normal,” underscoring the need to reliably identify more specific changes that could serve as additional antecedent markers for DAT.

Episodic memory loss has long been considered the primary marker for the first clinical manifestation of Alzheimer’s disease (e.g., Albert, Moss, Blacker, Tanzi, & McArdle, 2007; Albert, Moss, Tanzi, & Jones, 2001; Rubin et al., 1998; Storandt, Grant, Miller, & Morris, 2006). However, there also has been accumulating evidence documenting clear changes in components of attention in both healthy aging and in early stage DAT (for reviews, see Balota & Faust, 2001; Perry & Hodges, 1999). For example, in the classic Stroop task, Spieler, Balota, and Faust (1996) provided evidence that there is a disproportionate breakdown in the ability to inhibit the word code when naming colors in healthy older adults compared to young, and in DAT individuals, compared to age-matched controls. Furthermore, it has been argued that attentional breakdowns observed in healthy aging and in early stage AD are likely to be related to the episodic memory changes in these individuals (e.g., Balota, Burgess, Cortese, & Adams, 2002; Balota et al., 1999; Castel, Balota, & McCabe, 2009; Sommers & Huff, 2003). Memory researchers have long recognized the critical role of attention in declarative memory performance in both laying down distinct traces during encoding and directing search processes during retrieval (see e.g., Craik & Lockhart, 1972; Jacoby, 1999).

The standard approach in documenting cognitive decline is to compare mean-level performance across groups of participants. For example, if one is interested in measuring a characteristic such as processing speed, one typically uses the mean-level reaction time (RT) performance across multiple observations within a given participant. Variability across trials is often simply considered error variance. However, recently there has been interest in examining within-individual changes in variability in reaction time across trials within a task or occasions of testing as an indicator of neurocognitive function (for a review, see Hultsch, Strauss, Hunter & MacDonald, 2008). Indeed, within-task variability can be viewed as consistent with a breakdown in an attentional control system that maintains the goals of a task across time and controls competing pathways (for similar arguments, see West, 2001; West, Murphy, Armilio, Crai, & Stuss, 2002). Recent work (Bunce et al., 2007; see also Murtha, Cismaru, Waechter, & Chertkow, 2002) indicated that within-person variability in RTs was correlated with white matter hyperintensities in the frontal lobe, but not other brain regions (e.g., temporal or parietal areas). Stuss, Murphy, Binns,
and Alexander (2003) also found that patients with frontal lobe lesions (with the exception of ventral medial/orbitofrontal region) showed increased inconsistency in task performance. These results are consistent with the possibility that increased variability may reflect a breakdown in executive control systems that are dependent on the coordination of multiple-brain areas (for a review, see MacDonald, Nyberg & Bäckman, 2006).

There is evidence that intraindividual variability in processing speed increases as a function of normal aging (e.g., Hultsch, MacDonald, & Dixon, 2002; Hultsch et al., 2008). Moreover, there is some evidence that intraindividual variability across trials can actually be a better predictor of group status (healthy control vs. mild DAT) than mean-level performance. Hultsch, MacDonald, Hunter, Levy-Bencheton, and Strauss (2000) examined intraindividual standard deviations across trials and occasions for RT and memory tasks in healthy older adults, older adults with arthritis, and adults with mild dementia. They found increased intraindividual variability in the group with mild dementia relative to the two neurologically intact groups regardless of physical health status (i.e., healthy vs. arthritis), and the measure of intraindividual variability predicted neurocognitive status independent of mean-level performance. Because means and standard deviations tend to be highly correlated (see Faust, Balota, Spieler, & Ferraro, 1999), it is important that the measure of intraindividual variability takes into consideration overall differences in mean performance.

Because preclinical markers for AD may be present in some individuals prior to a clinical diagnosis and presently undetected due to the subtle nature of the cognitive changes seen early on, intraindividual variability may serve as a useful cognitive marker for the early onset of the disease. Indeed, Christensen et al. (2005) reported that a measure of intraindividual variability (mean independent variability; MIV) in both simple and choice RT tasks was greater for older adults (60 to 64 years of age) who met criteria for mild cognitive impairment (MCI) than healthy controls. In a more recent study, Dixon et al. (2007; see also Gorus, de Raedt, Lambert, Lemper, & Mets, 2008) also examined the utility of both speed (mean RT) and inconsistency (intraindividual standard deviation, ISD) in discriminating individuals with degrees of MCI (mild MCI and moderate MCI, based on individuals’ performance relative to norms on a set of reference cognitive tasks) from healthy older adults. More important, logistic regression analyses indicated that ISDs predicted cognitive status (healthy adults vs. mild MCI and mild MCI vs. moderate MCI) above and beyond mean-level performance. In light of their results and those of Christensen and colleagues, Dixon et al. argued that intraindividual variability may serve as an important indicator of early cognitive impairment, especially in more cognitively demanding tasks and at later ages.

The major purpose of the present study was to further examine the utility of trial-to-trial intraindividual variability in processing speed in attentional task performance in discriminating healthy aging from the very earliest stages of DAT. In the present study, three groups of participants afforded an examination of intraindividual variability associated with both healthy aging (young vs. healthy older adults) and the onset of early stage DAT (healthy older adults vs. very mild DAT). The clinical dementia rating (CDR) scale is used to identify individuals at the earliest detectable stages of DAT and is derived without knowledge of any independent cognitive testing. The power of the CDR in early diagnosis recently has been illustrated by Storandt et al. (2006) who compared the rate of progression of individuals who initially at enrollment met standard criteria for MCI (which presumes impairment, but does not yet meet criteria for dementia), and individuals with a CDR of 0.5 (very mild DAT) who initially did not meet standard criteria for MCI. Interestingly, the rate of decline was reliably greater for the MCI group compared with the CDR 0.5 DAT group, using both a psychometric composite and time to reach a more advanced stage of DAT (i.e., CDR 1) as outcome measures. This study indicates that it is possible to detect very mild DAT with the CDR scale even prior to what is considered by some to be MCI without dementia. Thus, the present well-characterized sample can provide a more refined examination of within-person variability as an early marker for the onset of DAT.

We also examined the relation between the estimate of intraindividual variability and biological markers in healthy older adults. The two variables we have identified were the presence of the ApoE4 allele and the CSF biomarkers, Aβ42, tau, and phosphorylated tau (ptau). Of course, the presence of the e4 allele is a well-established risk factor for DAT (e.g., Blacker et al., 1997; Corder et al., 1993; Henderson et al., 1995). Several studies have attempted to identify early cognitive markers for DAT by comparing healthy older adults who are at risk for DAT with those who are not. With respect to the present study, there recently has been increasing evidence suggesting that e4 carriers, compared to e4 noncarriers, produce some deficits in spatial attention and executive control systems (e.g., Parasuraman, Greenwood, & Sunderland, 2002; Rosen, Bergeson, Putman, Harwell, & Sunderland, 2002). However, it should also be noted that other studies have failed to find e4 differences in standard psychometric tests (e.g., Caselli et al., 2004; Wilson et al., 2002). In their meta-analysis, Small, Rosnick, Fratiglioni, & Backman (2004) argued that further work is needed in attentional/executive control measures to explore the influence of e4 status on cognitive performance.

Regarding CSF biomarkers, Fagan et al. (2007) reported decreased levels of CSF Aβ42 and increased levels of CSF tau and ptau in very mild DAT, consistent with prior studies of later stage DAT (for a review, see Sunderland et al., 2003), and the ratio of CSF tau/Aβ42 and ptau181/Aβ42 were predictive of conversion from healthy aging (CDR 0) to early stage dementia (CDR > 0). In a recent study, Nordlund et al. (2008) found that MCI individuals with abnormally high levels of tau and low levels of Aβ42 performed more poorly on some tests of attention and memory than MCI individuals with normal levels of tau and Aβ42. In the present study, we examined the relationship between CSF biomarkers and variability in healthy older adults to assess whether intraindividual variability also changes as a function of particular CSF markers.

The present study focused on standard tasks that tap aspects of attentional selection and switching (Stroop, Simon, task switching) that appear to be particularly sensitive to early stage DAT (Balota & Faust, 2001; Castel, Balota, Hutchison, Logan, & Yap, 2007; Spieler et al., 1996). As Dixon et al. (2007) suggested, within-person variability may be a more precise marker when the attentional demands of the task are greater. Indeed, West et al. (2002) also found that performance variability increased as a function of increased response set (0- vs. 1-back) in the N-back task, especially for healthy older adults. Thus, the tasks we used also vary with respect to the demands placed on the attentional system; with
the Simon task tapping spatial compatibility, the Stroop task tapping lexical compatibility, and the switching task tapping potentially higher level control systems. The primary dependent variable in the present analyses is the coefficient of variation (CoV). The CoV is computed by dividing an individual’s standard deviation by their mean (SD/M). This measure has the advantage of taking into consideration overall speed that is critical when comparing across age and dementia groups that vary substantially in terms of overall RT (for an excellent review of alternative measures of variability, see Hultsch et al., 2008).

Method

Participants

A total of 291 individuals were recruited from the Washington University Alzheimer’s Disease Research Center (ADRC) for this study. All ADRC participants were originally screened for depression, untreated hypertension, reversible dementias, and other disorders that could potentially produce cognitive impairment. The inclusionary and exclusionary criteria for DAT are consistent with the criteria for “probable AD” of the National Institute of Neurological and Communications Disorders and Stroke-Alzheimer’s Disease and Related Disorders Association (McKhann et al., 1984). The presence and severity of dementia were assessed according to the Washington University Clinical Dementia Rating (CDR) scale (Morris, 1993; Morris et al., 1988), with CDR 0, 0.5, 1, 2, and 3 representing no dementia, very mild dementia, mild dementia, moderate dementia, and severe dementia, respectively. The CDR is based on a 90-min clinical interview that assesses the participant and also relies on information from their family members. This interview assesses potential changes in participants’ cognitive and functional abilities in the areas of memory, orientation, judgment and problem solving, community affairs, home and hobbies, and personal care relative to previous behavior. The recruitment and assessment methods permit the diagnosis of DAT in individuals who elsewhere may be characterized as MCI (for details, see Berg et al., 1998; Morris et al., 2006). We also recruited 35 healthy young adults from the undergrad-

| Table 1 Psychometric Means and Standard Deviations as a Function of Group |
|-----------------|-----------------|
|                 | Healthy old     | Very mild DAT |
| Logical Memory  | 12.09 (3.63)    | 7.81* (4.60)  |
| Forward Digit Span | 6.61 (1.28)    | 6.36 (1.20)   |
| Backward Digit Span | 4.96 (1.30)    | 4.41 (1.23)   |
| WMS Associate Recall | 14.68 (4.08)  | 9.69 (3.95)   |
| Word Fluency S–P  | 32.81 (10.81)  | 26.03* (10.21) |
| WAIS Information  | 21.94 (4.17)   | 18.25* (4.95) |
| WAIS Digit Symbol | 48.85 (11.05)  | 37.17* (11.32) |
| WAIS Similarities  | 25.81 (3.99)   | 22.27* (5.48) |
| Trailmaking Part A | 32.99 (13.13)  | 43.17* (24.89) |
| Trailmaking Part B | 86.78 (38.79)  | 126.41* (54.82) |
| Boston Naming    | 56.10 (3.90)   | 52.39* (7.89) |
| Animal fluency   | 20.32 (5.92)   | 15.05* (5.60) |
| Selective Reminding | 30.46 (6.13)  | 19.52* (9.00) |
| MMSE             | 29.09 (1.170)  | 26.95* (2.36) |
| Age              | 71.75 (8.31)   | 75.25* (7.68) |
| Years of education | 15.41 (2.71)  | 14.67 (3.04)  |

Note. WMS = Wechsler Memory Scale; WAIS = Wechsler Adult Intelligence Scale; MMSE = Mini-Mental State Examination. *p < .05.

Washington University and all participants provided their informed consent at the beginning of the study.

Psychometric Testing

Each ADRC participant was administered a 2-hr standard neuropsychological battery in a separate testing session, by an examiner who was unaware of the participant’s CDR score. Memory was assessed with Logical Memory, Forward and Backward Digit Span, and Associate Memory from the Wechsler Memory Scale (WMS; Wechsler & Stone, 1973) and the Selective Reminding Test (Grober et al., 1988). General intelligence was assessed with Information, Digit Symbol, and Similarities subtests of the Wechsler Adult Intelligence Scale (WAIS; Wechsler, 1955). Visual perceptual-motor performance was assessed with Parts A and B of the Trail Making Test (Armitage, 1946). The Boston Naming Test (Goodglass & Kaplan, 1983b), the Word Fluency Test S–P (Thurstone & Thurstone, 1949), and the Animal Naming Test (Goodglass & Kaplan, 1983a) were administered as tests of semantic/lexical retrieval. The means and standard deviations of the psychometric measures for the healthy older adults and individuals with very mild DAT are presented in Table 1. A series of t tests indicated that performance on all of the measures was significantly different between groups (all p < .05, ηp² > .03), with the exception of WMS forward digit span (p = .19, ηp² = .01) and years of education (p = .07, ηp² = .01). Thus, the CDR classification of healthy control (CDR 0) versus very mild DAT (CDR 0.5) is further supported by objective psychometric testing.

Genotyping and CSF Biomarkers

Genotyping for the ApoE alleles (ε2, ε3, ε4) was available for 151 healthy older adults from the ADRC (ns for ε2 = 22, ε3 = 82, ε4 = 4, ε34 = 38, ε44 = 5). Due to the small ns in
some of the allele groups, participants were grouped according to
the presence (ɛ 4/H11001, n /H1100547) versus absence of at least one ɛ 4 allele
(ɛ 4−, n = 104). There was no difference in education for ɛ 4 +
versus ɛ 4− participants, p = .89, ƞ²p = .000, however the ɛ 4+
group was slightly younger than the ɛ 4− group, t(149) = 2.00, p = .047, ƞ²p = .02. In addition, CSF biomarkers (Aβ42, Tau/Aβ42,
and Ptau181/AB42) were available for 84 healthy older adults (for
details on CSF collection, processing, and assessment, see Fagan et
al., 2007).

Apparatus
A Pentium II IBM compatible computer was used to control the
display of the stimuli and to collect participants’ responses. Display of
all stimuli was synchronized with the vertical retrace of the monitor to
control for presentation duration. The stimuli were displayed on a
15-inch monitor. A voice-operated relay (Model #200A Psychology
Software Tools, Pittsburgh, PA) was interfaced with the computer to
measure voice onset latency in the Stroop task.

Stroop Task
The word stimuli consisted of four color words (red, blue, green,
yellow) and four neutral words (bad, poor, deep, legal). The neutral
words were chosen to match the color words in phoneme onset and
word frequency. The task included a block of 104 word naming trials
and a block of 104 color naming trials. There were 36 congruent, 32
neutral, and 36 incongruent trials in each block. In the congruent
trials, each color word appeared nine times. In the incongruent trials,
each color word appeared three times in each of three other colors
(e.g., blue appeared in red, green, yellow three times). In the neutral
trials, each word appeared two times in each of the four colors. The
order of trials was randomized in each block and the order of blocks
(word or color) was counterbalanced across participants.

Participants were given 16 practice trials before each block of
trials. For the word (or color) naming trials, participants were
instructed to read the words (or colors in which the word appeared)
as quickly and as accurately as possible. At the beginning of each trial
a fixation point appeared for 500 ms followed by a blank
screen for 50 ms. The stimulus word then appeared on the screen
for 5 s or until the participant responded. The experimenter re-
corded the response as correct, incorrect, or a voice key error (e.g.,
stutters, false starts, or any noise that triggered the voice key).
Participants were given breaks between trial blocks. Because there
is relatively little attentional control exerted in the word-naming
trials, we focus on the color-naming trials in the present paper.

Simon Task
The stimulus display consisted of a white central fixation cross
on the screen and white arrow stimuli (measuring approximately 4
cm in length and 2 cm in height) presented on a black background.
The peripheral locations of the arrow (left and right) were situated
5° on the horizontal plane from the central fixation. Participants
were told that they would be presented with an arrow pointing to
either the left or right on the screen. The arrow could appear on the
left half, right half, or center of the screen. Participants were told to
ignore the arrow location on the screen and respond according to the
arrow direction by pressing a key on either the left (i.e., q key) or the
right side (i.e., p key) of the keyboard that corresponded to the arrow
direction. In the congruent trials, the arrow direction corresponded
to the arrow location (e.g., left facing arrow on the left side of the
screen). In the incongruent trials, the arrow direction was opposite
to the arrow location (e.g., left facing arrow on the right side of the
screen). In the neutral trials, the arrow appeared at the center of
the screen. Each trial began with a 500-ms central fixation cross,
followed by the onset of an arrow, which stayed on the screen until
the participant made a response or until 5 s elapsed. Once a
response was made, the screen cleared and accuracy feedback was
presented for 400 ms. There were 12 practice trials (4 congruent, 4
incongruent, and 4 neutral) and 120 experimental trials (40 congru-
ent, 40 incongruent, and 40 neutral). The 40 neutral trials were
included to ensure that participants would keep fixated at the
center of the screen. These different trial types were randomly
intermixed for each participant.

Results
Although our focus is on the CoV as a measure of intraindivi-
dual variability, we first present the mean RT and error data for
each attention task as a function of participant group and task
condition to ensure that these general indicators of task perform-
ance replicate prior literature. We also performed z-transformed
RT analyses to determine if any condition effects were due to
general slowing (Faust et al., 1999). For sake of brevity, we will
not report these findings given that all crucial Group × Condition

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interactions remained statistically significant in the z-score analyses. The CoV data is presented for each task as a function of participant group and then as a function of ApoE status in the healthy older adults. We will first present the overall CoV (overall standard deviation divided by overall mean) in each task to provide a more stable estimate of intraindividual variation and then in each task we will focus on the CoV in the incongruent/mixed-switch conditions in which the attentional control system was most heavily taxed. In all direct comparisons of healthy older adults with very mild DAT, we covaried out age. Finally, the correlations among the CoV and CSF biomarkers will be presented. The partial eta-square ($\eta_p^2$) indicates the effect size of our analyses.

**Stroop Task Mean RT, Errors, and CoV**

The mean RTs for correct color-naming trials as a function of group and congruency condition are displayed in Figure 1. Participants’ mean RTs and errors were separately submitted to a 3 (group) × 3 (congruency: congruent, neutral, incongruent) mixed-factor analysis of variance (ANOVA). There were main effects of group, for RTs: $F(2, 300) = 37.47$, $MSE = 81,389.44$, $p < .001$, $\eta_p^2 = .20$; for errors: $F(2, 300) = 7.74$, $MSE = 15.87$, $p = .001$, $\eta_p^2 = .05$; and congruency, for RTs: $F(2, 600) = 350.03$, $MSE = 3,836.02$, $p < .001$, $\eta_p^2 = .54$; for errors: $F(2, 600) = 64.24$, $MSE = 9.19$, $p < .001$, $\eta_p^2 = .18$. More important, there was a

Figure 1. Mean reaction times (RTs) in Stroop, Simon, and task switching as a function of condition and group. Error bars indicate standard errors of means. DAT = dementia of Alzheimer’s type.
significant Group × Congruency interaction in both RTs and errors, for RTs: \( F(4, 600) = 26.89, \text{MSE} = 3,836.02, p < .001, \eta^2_p = .15 \); for errors: \( F(4, 600) = 8.24, \text{MSE} = 9.19, p < .001, \eta^2_p = .05 \). Post hoc tests were conducted comparing the Stroop congruency effect (incongruent–congruent) across groups. The congruency effect was larger for the very mild DAT group compared with the healthy older group (for RTs: \( p < .001, \eta^2_p = .17 \); for errors: \( p = .001, \eta^2_p = .06 \), and larger for the healthy older adults than the young adults in RTs (\( p = .003, \eta^2_p = .04 \)). However, there was no age-related difference in the congruency effect in errors (\( p = .50, \eta^2_p = .002 \)). Hence, we replicated the findings that indicated a breakdown in the attentional control system due to healthy aging and DAT pathology (e.g., Spieler et al., 1996).

The overall CoV for color-naming trials as function of group is displayed in Figure 2. A one-way ANOVA indicated that the overall CoV increased across groups, \( F(2, 300) = 47.07, \text{MSE} = 58,442.43, p < .001, \eta^2_p = .23 \); for errors: \( F(2, 281) = 13.78, \text{MSE} = 19.02, p < .001, \eta^2_p = .09 \); and congruency, for RTs: \( F(2, 562) = 208.39, \text{MSE} = 1,905.93, p < .001, \eta^2_p = .43 \); for errors: \( F(2, 562) = 60.53, \text{MSE} = 8.60, p < .001, \eta^2_p = .18 \). More important, there was also a significant Group × Congruency interaction in both RTs and errors, for RTs: \( F(2, 562) = 17.31, \text{MSE} = 1,905.93, p < .001, \eta^2_p = .11 \); for errors: \( F(4, 562) = 4.81, \text{MSE} = 8.60, p = .001, \eta^2_p = .03 \). Post hoc tests were conducted comparing the Simon congruency effect (incongruent–congruent) across groups. The congruency effect was larger for the very mild DAT group than the healthy older group (for RTs: \( p < .001, \eta^2_p = .09 \); for errors: \( p = .003, \eta^2_p = .03 \), and larger for healthy older adults than for young adults in RTs (\( p < .001, \eta^2_p = .06 \)) but not in errors (\( p = .75, \eta^2_p = .00 \)). Hence, we replicated the findings of a breakdown in the attentional control system due to healthy aging and DAT pathology in the Simon task (e.g., Castel et al., 2007).

The overall CoV as a function of group is displayed in Figure 2. A one-way ANOVA indicated that the overall CoV increased across groups, \( F(2, 281) = 14.48, \text{MSE} = .006, p < .001, \eta^2_p = .09 \). Post hoc tests showed that the CoV was larger for the very mild DAT group than for the healthy older group (\( p < .001, \eta^2_p = .08 \)). There was no significant difference in the overall CoV between young and healthy older adults (\( p = .309, \eta^2_p = .01 \)). The CoV for incongruent trials was also computed for each individual. A one-way ANOVA indicated that the incongruent CoV also increased across groups, \( F(2, 281) = 7.48, \text{MSE} = .006, p < .001, \eta^2_p = .05 \). Post hoc tests showed that the incongruent CoV was larger for the very mild DAT group (.230) than the healthy older group (.188; \( p = .001, \eta^2_p = .04 \)). There was no difference in the incongruent CoV between young (.183) and healthy older adults (.188; \( p = .71, \eta^2_p = .001 \)).

**Simon Task Mean RT, Errors, and CoV**

The mean RTs for correct trials as a function of group and congruency condition are displayed in Figure 1. Participants’ mean RTs and errors were separately submitted to a 3 (group) × 3 (congruency: congruent, neutral, incongruent) mixed-factor ANOVA. There were main effects of group, for RTs: \( F(2, 281) = 41.08, \text{MSE} = 58,442.43, p < .001, \eta^2_p = .23 \); for errors: \( F(2, 281) = 13.78, \text{MSE} = 19.02, p < .001, \eta^2_p = .09 \); and congruency, for RTs: \( F(2, 562) = 208.39, \text{MSE} = 1,905.93, p < .001, \eta^2_p = .43 \); for errors: \( F(2, 562) = 60.53, \text{MSE} = 8.60, p < .001, \eta^2_p = .18 \). More important, there was also a significant Group × Congruency interaction in both RTs and errors, for RTs: \( F(2, 562) = 17.31, \text{MSE} = 1,905.93, p < .001, \eta^2_p = .11 \); for errors: \( F(4, 562) = 4.81, \text{MSE} = 8.60, p = .001, \eta^2_p = .03 \). Post hoc tests indicated that the CoV was larger for very mild DAT (health older controls \( .205; \) and for individuals with very mild DAT \( .244 \)) than healthy older adults \( .205; p < .001, \eta^2_p = .06 \).
were separately submitted to a 3 (group) × 2 (switch vs. nonswitch trials) mixed-factor ANOVA. There were main effects of group, for RTs: F(2, 283) = 28.46, MSE = 2,363,129.28, p < .001, 𝜇_p^2 = .17; for errors: F(2, 283) = 35.63, MSE = 112.88, p < .001, 𝜇_p^2 = .20; and switch trials, for RTs: F(1, 283) = 153.34, MSE = 124,740.73, p < .001, 𝜇_p^2 = .35; for errors: F(1, 283) = 18.10, MSE = 12.86, p < .001, 𝜇_p^2 = .06. More important, there was a significant Group × Switch interaction in both RT and errors, for RTs: F(2, 283) = 5.56, MSE = 124,740.73, p = .004, 𝜇_p^2 = .04; for errors: F(2, 283) = 3.21, MSE = 12.86, p = .04, 𝜇_p^2 = .02. Post hoc tests were conducted comparing the local switch costs (switch–nonswitch) across groups. The local switch cost was larger for the healthy older group than the very mild DAT group in RT, but was smaller in errors (for RTs: p = .01, 𝜇_p^2 = .03; for errors: p = .03, 𝜇_p^2 = .02). However, there was no age-related difference in the local switch cost in RTs (p = .21, 𝜇_p^2 = .01) or in errors (p = .53, 𝜇_p^2 = .02).

General cost. The mean RTs for correct trials as a function of group and switch condition are displayed in Figure 1. To compute the “general cost” of switching, we compared the correct trials in the pure block and the nonswitch correct trials in the mixed block. Participants’ mean RTs and errors were separately submitted to a 3 (group) × 2 (pure vs. nonswitch trials) mixed-factor ANOVA. There were main effects of group, for RTs: F(2, 283) = 40.87, MSE = 958,599.37, p < .001, 𝜇_p^2 = .22; for errors: F(2, 283) = 23.16, MSE = 64.67, p < .001, 𝜇_p^2 = .14; and trial block, for RTs: F(1, 283) = 146.77, MSE = 450,398.79, p < .001, 𝜇_p^2 = .34; for errors: F(1, 283) = 14.94, MSE = 23.33, p < .001, 𝜇_p^2 = .05. More important, there was a significant Group × Trial Block interaction in both RTs and errors, for RTs: F(2, 283) = 17.42, MSE = 450,398.79, p < .001, 𝜇_p^2 = .11; for errors: F(2, 283) = 14.44, MSE = 23.33, p < .001, 𝜇_p^2 = .09. Post hoc tests were conducted comparing the general switch costs (nonswitch–pure trials) across groups. The general switch cost was not different between the two groups in RTs (p = .10, 𝜇_p^2 = .01), but was larger for the very mild DAT group than the healthy older group in errors (p < .001, 𝜇_p^2 = .08). The general switch cost was larger for healthy older adults than young adults (for RTs: p < .001, 𝜇_p^2 = .13; for errors: p = .054, 𝜇_p^2 = .02).

The overall CoV as function of group is displayed in Figure 2. A one-way ANOVA indicated that the overall CoV increased across groups, F(2, 283) = 27.89, MSE = 0.02, p < .001, 𝜇_p^2 = .17. Post hoc tests indicated that the CoV was larger for healthy older adults than for young adults (p < .001, 𝜇_p^2 = .15) and for very mild DAT than for healthy older adults (p = .002, 𝜇_p^2 = .04). The CoV for mixed-switch trials was also computed for each individual. A one-way ANOVA indicated that the mixed-switch CoV also increased across groups, F(2, 283) = 34.64, MSE = 0.02, p < .001, 𝜇_p^2 = .20. Post hoc tests indicated that the mixed-switch CoV was larger for healthy older adults (.277) than for young adults (.230; p = .003, 𝜇_p^2 = .04) and larger for individuals with very mild DAT (.433) than for healthy older adults (.277; p < .001, 𝜇_p^2 = .15).

CoV and ApoE in Healthy Aging

We next examined the relationship between ApoE status and variability in the healthy older adults in each attention task to assess whether intraindividual variability can discriminate healthy individuals who are at risk versus not at risk for DAT. First, it should be noted that there were no significant differences in psychometric performance as a function of ApoE status in the healthy older adults, with the exception of the Selective Reminding test (ε4− = 31.3; ε4+ = 29.0; p = .03, 𝜇_p^2 = .03) and Trailmaking A (ε4− = 35.1; ε4+ = 30.0; p = .03, 𝜇_p^2 = .04), where the ε4+ group actually showed better performance in this latter task. Also, the ε4+ group was slightly younger than the ε4− group (70.2 vs. 73.2, p = .047, 𝜇_p^2 = .03), therefore age was used as a covariate. We did not find any differences between ε4+ and ε4− individuals for the mean and standard deviation measures of all conditions across all three attention tasks (all ps > .17).

First, we examined the overall CoV in the Stroop task as a function of ApoE status in the healthy older group. There was no significant difference in the overall CoV between ε4+ (.230) and ε4− (.218) individuals, F(1, 140) = 2.17, MSE = 0.002, p = .14, 𝜇_p^2 = .02, although the means were in the predicted direction. Next, we examined the CoV for Stroop incongruent trials as a function of ApoE status. As can be seen in Figure 3, the CoV was larger in the ε4+ group (.220) than in the ε4− group (.199), F(1, 140) = 4.46, MSE = 0.003, p = .037, 𝜇_p^2 = .03. For the Simon task, neither the overall CoV nor the CoV in the incongruent condition yielded a significant main effect of ApoE status, (p = .73, 𝜇_p^2 = .001, and p = .83, 𝜇_p^2 = .001, respectively). Similarly, for task switching neither the overall CoV (although the means were in the predicted direction) nor the CoV in the mixed-switch condition yielded a significant main effect of ApoE status, (p = .11, 𝜇_p^2 = .01 and p = .936, 𝜇_p^2 = .00, respectively). Hence, it appears that the CoV difference between ε4+ and ε4− individuals is slightly more sensitive to the conflict in the Stroop incongruent condition.

CoV Differences Beyond Standard Psychometrics

To examine whether CDR status (i.e., 0 healthy old vs. 0.5 very mild DAT) could predict the CoV, above and beyond standard psychometric measures, we conducted a series of linear regression analyses. In each linear regression analysis, we entered the participants’ age and one of 14 psychometric measures in Table 1 in the first and second steps of the linear regression model, respectively. Then, we entered CDR status in the last step of the model. The dependent measures of these linear regression models were Stroop...
incongruent CoV, Simon incongruent CoV, or task switching mixed-switch CoV. Table 2 presents the $R^2$ changes and significance levels of CDR status when it was entered in the last step of the linear regression analyses on predicting the incongruent CoV in the three attention tasks. There are a number of points to note here. First, although the Simon CoV clearly predicts unique performance compared to most of the psychometric measures, the Stroop CoV and the switching CoV clearly do better overall. Second, the Simon task has particular overlap with the memory measures. Third, and most important, 38 out of the 42 CDR-status predictors were significant in directional tests (i.e., $p < .10$), and 34 out of the 42 CDR-status predictors were significant, $p < .05$. We also performed the same regression analyses on mean performance in each of the comparable task conditions, and only 16 out of 42 CDR-status predictors reached significance in a directional test and only 11 reached the $p < .05$ level. Clearly, there are reliable differences in CoV as a function of CDR status above and beyond the standard psychometric measures, and this pattern is larger than the mean RT in each of the comparable conditions.

**CoV and CSF Biomarkers**

We now examine the association between the CSF biomarkers (Aβ42, Tau/Aβ42, Ptau$_{181}$/Aβ42), which are predictive of the onset of DAT (see Fagan et al., 2007) in the healthy control (CDR = 0) individuals. Thus, we examined the correlations of these biomarkers with the CoV across the three attention tasks, while treating age and education as covariates.1 Interestingly, in the task switching, the overall CoV and the CoV on mixed-switch trials were significantly correlated with all of these CSF biomarkers, as displayed in Table 3. It should be noted that all of the correlations were in the predicted direction indicating increased individual variability with CSF biomarkers that suggest the presence of AD pathology (i.e., reduced Aβ42, and increased Tau/

### Table 2

**The $R^2$ Changes of CDR Status (0 vs. 0.5) When Entered in the Last Step of Linear Regression Analyses on Predicting the Incongruent CoV**

<table>
<thead>
<tr>
<th>Task</th>
<th>Stroop</th>
<th>Simon</th>
<th>Task Switching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logical Memory</td>
<td>0.06**</td>
<td>0.02**</td>
<td>0.06**</td>
</tr>
<tr>
<td>Forward Digit Span</td>
<td>0.07**</td>
<td>0.03**</td>
<td>0.14**</td>
</tr>
<tr>
<td>Backward Digit Span</td>
<td>0.05**</td>
<td>0.03**</td>
<td>0.11**</td>
</tr>
<tr>
<td>WMS Associate Recall</td>
<td>0.02**</td>
<td>0.01</td>
<td>0.04</td>
</tr>
<tr>
<td>Word Fluency S–P</td>
<td>0.05**</td>
<td>0.02**</td>
<td>0.12</td>
</tr>
<tr>
<td>WAIS Information</td>
<td>0.03**</td>
<td>0.02**</td>
<td>0.06**</td>
</tr>
<tr>
<td>WAIS Digit Symbol</td>
<td>0.03**</td>
<td>0.00</td>
<td>0.05**</td>
</tr>
<tr>
<td>WAIS Similarities</td>
<td>0.03**</td>
<td>0.02**</td>
<td>0.08**</td>
</tr>
<tr>
<td>Trailmaking Part A</td>
<td>0.05**</td>
<td>0.02**</td>
<td>0.13**</td>
</tr>
<tr>
<td>Trailmaking Part B</td>
<td>0.03**</td>
<td>0.01</td>
<td>0.05**</td>
</tr>
<tr>
<td>Boston Naming</td>
<td>0.07**</td>
<td>0.03**</td>
<td>0.11</td>
</tr>
<tr>
<td>Animal Fluency</td>
<td>0.04**</td>
<td>0.02**</td>
<td>0.09**</td>
</tr>
<tr>
<td>Selective Reminding</td>
<td>0.02**</td>
<td>0.00</td>
<td>0.03**</td>
</tr>
<tr>
<td>MMSE</td>
<td>0.01*</td>
<td>0.01</td>
<td>0.05**</td>
</tr>
</tbody>
</table>

Note. CDR = clinical dementia rating; CoV = coefficient of variation; WMS = Wechsler Memory Scale; WAIS = Wechsler Adult Intelligence Scale; MMSE = Mini-Mental State Examination.

1 $p < .10$. ** $p < .05$. *** $p < .01$.

### Table 3

**Partial Correlations Between CoV and CSF Biomarkers in Healthy Older Adults**

<table>
<thead>
<tr>
<th></th>
<th>Aβ42</th>
<th>Tau/Aβ42</th>
<th>Ptau$_{181}$/Aβ42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall sample</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task switching</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall CoV</td>
<td>–.32*</td>
<td>.28*</td>
<td>.27*</td>
</tr>
<tr>
<td>Mixed-switch CoV</td>
<td>–.36*</td>
<td>.33*</td>
<td>.38*</td>
</tr>
<tr>
<td>ε4+ individuals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall CoV</td>
<td>–.32</td>
<td>.42*</td>
<td>.45*</td>
</tr>
<tr>
<td>Incongruent CoV</td>
<td>–.26</td>
<td>.40*</td>
<td>.40*</td>
</tr>
<tr>
<td>Task switching</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall CoV</td>
<td>–.37</td>
<td>.44*</td>
<td>.30</td>
</tr>
<tr>
<td>Mixed-switch CoV</td>
<td>–.33</td>
<td>.29</td>
<td>.31</td>
</tr>
</tbody>
</table>

Note. CoV = coefficient of variation; CSF = cerebrospinal fluid. * $p < .05$. ** $p < .01$.

Aβ42 and Ptau$_{181}$/Aβ42). However, these biomarkers were not reliably correlated with any CoV measures in the Stroop and Simon tasks with the full sample of healthy controls (all $r < .10$).2

We next restricted our CoV–CSF biomarker analyses to ε4+ individuals only (i.e., those healthy older adults who are at risk for DAT; $n = 26$). Due to the reduced sample size, some of the correlation coefficients did not reach significance. As shown in the bottom of Table 3, it is indeed the case for the overall CoV in the switching task. In fact, even the Stroop overall CoV and incongruent CoV were now correlated with CSF biomarkers in the predicted direction. Thus, this indicates that the magnitude of intraindividual variability is further accentuated for those healthy older individuals with at least one ε4+ allele.

### Between-Task Variability

Finally, between-task variability across participant groups was examined by first computing each participant’s overall mean in each task, then the standard deviation of these overall task means and in turn, the CoV (overall standard deviation/overall tasks means) across the tasks (see Figure 4). This measure reflects the variability in performance across the tasks, above and beyond mean performance. A one-way ANOVA indicated that the between task CoV increased across groups, $F(2, 302) = 10.89, MSE = 0.03, p < .001, \eta^2_p = .07$. Post hoc tests indicated that there was a significant increase in the task CoV with healthy aging (young vs. healthy older adults, $p < .003, \eta^2_p = .04$) and with the onset of dementia (healthy older adults vs. individuals with very mild DAT, $p = .002, \eta^2_p = .04$). Therefore, in addition to the increase in variability across trials within a task, there is also

1 The scatterplots were examined and any data points that were 3 standard deviation units or more from the regression line were identified as outliers and removed from the correlational analysis. All reported effects were also reliable when these outliers were not removed from the correlational analyses.

2 It should be noted that the overall mean RT was not significantly correlated with the CSF biomarkers for any of the attention tasks (all $p > .07$).

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[2] Post hoc tests indicated that there was a significant increase in the task CoV with healthy aging (young vs. healthy older adults, $p < .003, \eta^2_p = .04$) and with the onset of dementia (healthy older adults vs. individuals with very mild DAT, $p = .002, \eta^2_p = .04$). Therefore, in addition to the increase in variability across trials within a task, there is also.
evidence of an increase in variability across tasks within individuals across groups. These findings are consistent with a recent study by Holtzer, Verghese, Wang, Hall, and Lipton (2008), who found that the risk of dementia increased as a function of higher within-person between test variability, even after taking into account neuropsychological test performance. However, whereas we used three attention tasks with differential task demands in the current study, Holtzer et al. used three tests that represented different cognitive domains, including verbal intelligence (WAIS–R vocabulary subtest; Wechsler, 1981), attention control/executive function (WAIS–R digit symbol test; Wechsler, 1981), and memory (free and cued selective reminding test).

Discussion

The purpose of the present research was to provide a large scale examination of (a) the utility of trial-to-trial intraindividual variability in processing speed in three standard attention tasks in discriminating healthy aging from the very earliest stages of DAT; and (b) the relationship between ApoE4 status and variability in healthy older adults to determine whether within-person variability can discriminate healthy individuals at risk versus not at risk for DAT, along with specific CSF biomarkers predictive of AD.

Discriminating Healthy Aging and Very Mild DAT

The mean level performance in the present tasks are consistent with the notion of a breakdown in attentional control in early stage DAT (see also Balota & Faust, 2001; Castel et al., 2007; Duchek & Balota, 2005; Spieler et al., 1996). First, in the Stroop task, there was evidence for a larger congruency effect in RT and more errors in the incongruent trials for individuals with very mild DAT compared with healthy older adults. Thus, there is evidence for a disruption in the ability to control the prepotent “word” response in early stage DAT. Similarly, in the Simon task, individuals with very mild DAT showed a larger congruency effect in RTs and more errors in incongruent trials than healthy older adults, indicating more difficulty controlling the prepotent pathway when a conflict is presented in terms of incongruent mapping between a stimulus and the appropriate response. An interesting pattern of data emerged in task switching. The very mild DAT group actually showed smaller local switching costs (switch–nonswitch trials) in RTs than healthy older and young adults, yet more errors on switch trials, suggesting that they are less “tuned” to the constraints of the task and thus less affected by the switching within trial blocks, again suggesting a breakdown in attentional control systems that maintain the goals of the task. More important, all of these effects were also reliable in the z-score transformed data and thus are not simply a reflection of overall slowing (see Faust et al., 1999).

In terms of intraindividual variability, the results across the three attention tasks are also straightforward. We chose these tasks because they are particularly sensitive to early stage DAT (e.g., Castel et al., 2007; Spieler et al., 1996). Indeed, there was a clear increase in within-person variability as a function of healthy aging (young vs. old) in both Stroop and task switching, and more important, as a function of DAT (healthy old vs. very mild DAT) in Stroop, Simon, and task switching. In all three tasks, relative to healthy older adults, individuals with very mild DAT showed increased variability in overall performance as well as in incongruent/mixed-switch trials, indicating that the increase in intraindividual variability represents a general characteristic of overall performance and not just for the most difficult condition. Hence, these results are consistent with Christensen et al. (2005) and Dixon et al. (2007) who reported increased variability in MCI individuals and argued that inconsistency in performance may serve as an additional marker for very early cognitive impairment.

As noted in the Introduction, there are numerous ways to measure variability, and we chose the relatively simple measure of the CoV, which is the ratio of the standard deviation and mean response latency. Because it is possible that the present results may be a reflection of this particular measure, we also used a covariance technique as converging evidence in which we partialed out the mean RT in an analysis of covariance to determine if there are reliable differences between the healthy old and the very mild DAT individuals in the standard deviations. The results of this alternative approach are also quite clear. There is a reliable difference between the healthy control and very mild DAT groups for all three attention tasks. For example in the incongruent condition, after partialed out the mean RT for each of the three tasks, there was a significant group difference in the standard deviation (Stroop, $p = 0.003$, $\eta^2_p = 0.31$; Simon, $p = 0.047$, $\eta^2_p = 0.16$; task switching, $p < 0.001$, $\eta^2_p = 0.113$).

It should be emphasized that the current study provided a comparison of a well-characterized group of individuals in the earliest detectable stage of DAT with healthy older adults, free of any cognitive impairment. A designation of very mild DAT on the CDR scale (CDR 0.5) denotes cognitive impairment at an early stage comparable to MCI without dementia (Storandt et al., 2006). Dixon et al. (2007) did not use standard MCI diagnostic criteria, but instead defined MCI based on individuals’ performance relative to norms on a set of reference cognitive tasks. Thus, it is not entirely clear how the level of impairment of their MCI groups compared with our very mild DAT group (although the MMSE scores for their MCI groups, ranged from 27.85 to 29.00, were slightly higher than our very mild DAT group, 26.95). It is interesting that Dixon et al. found the most reliable group discrimination of mild MCI and healthy aging among their older participants (74 to 92; $M$ age = 79.98), whereas our groups were slightly younger (healthy older adults = 71.75; very mild DAT = 75.25), and we still found that intraindividual variability discriminated healthy aging from very mild DAT.
Discriminating Healthy Controls at Risk

Turning to the results from the biomarkers in healthy control individuals, the overall Stroop CoV was numerically larger in ε4+ individuals, compared to ε4– individuals, although this difference did not quite reach statistical significance \((p = .12)\). However, the ε4+ individuals did show reliably greater within-person variability than ε4– individuals on the more demanding Stroop incongruent trials. It is important to note that there was no difference in mean RT in incongruent trials as a function of ApoE status \((p = .66)\), nor were there any differences in psychometric test performance, with the exception of the selective reminding task. Thus, the variability in performance in the conflict condition of the Stroop task may potentially be a useful indicator for the risk for DAT.

These results are consistent with other studies in the literature in which ε4+ related deficits are only apparent when experimental procedures are used that tap early aspects of visual attentional selection, rather than more global measures of cognition (e.g., Greenwood, Lambert, Sunderland, & Parasuraman, 2005; Rosen et al., 2002; 2004). In a meta-analysis, Small et al. (2004) argued that the ε4 effect on cognitive performance in healthy aging is subtle and confined to more specific aspects of cognition, such as retrospective memory and executive function. Clearly, such executive control is paramount to effective performance in the Stroop task. In fact, Parasuraman et al. (2002) argued that attentional selection, in particular, was impaired in ε4 carriers and was an early sensitive marker for DAT. Of course, the variability in the Simon task was not sensitive to ApoE status. It is possible that the attentional selection involved in a relatively simpler spatial S–R compatibility task, such as the Simon task, is less demanding and so is not as sensitive to ApoE status in healthy older adults. Hence, the attentional selection component of the Stroop task, in particular, and the measure of intraindividual variability in attentional control mechanisms may provide an antecedent marker for the later onset of DAT (also see Balota et al., 2009).

The potential for attention measures as an early marker for individuals at risk for developing DAT is also supported by the CSF biomarker data in our healthy older adults. As mentioned above, Fagan et al. (2007) and Li et al. (2007) found that the ratio of CSF tau/β42 and ptau181/β42 predicted conversion from healthy aging to early stage dementia (3 to 4 years). In addition, cognitively normal individuals with cortical amyloid deposition can be identified by the presence of low CSF β42 (Fagan et al., 2006; 2007). Our results indicate that greater within-person variability in task switching in healthy controls is modestly associated with decreased CSF β42 and increased CSF tau/β42 and ptau181/β42, which are likely makers for the presence of amyloid deposition (β42) and tangles (tau) in the brain. It is interesting that neither Stroop nor Simon performance correlated with the biomarkers when we examined the full sample of healthy older adults. However, when we restricted our analyses to the ε4+ individuals only (i.e., those at greater risk for the onset of DAT), we found that Stroop overall CoV and incongruent CoV were reliably correlated with the CSF biomarkers. Given that the switching task was more difficult, as evidenced by the largest CoV across all groups and the lowest overall RT in this task, one might speculate that the relationship between these CSF biomarkers and task performance in healthy older adults will be apparent when greater demands are placed on the attentional system, as in the case of task switching\(^3\) (for a similar argument, see West et al., 2002) and/or when the risk for the onset of DAT is greater, as was the case in the Stroop task for the ε4+ individuals. To our knowledge, this is the first report of such a relationship between intraindividual variability, as a potential behavioral marker, and CSF biomarkers in healthy older adults. Of course given the relatively modest relationship we found in this study, further research is clearly warranted.

Based on the pattern of intraindividual variability for our healthy older adults, one might speculate that lower level attentional selection tasks, such as Stroop, may be more sensitive to ApoE 4 status. On the other hand, more complex attention tasks, such as task switching, may be more sensitive to CSF biomarkers as indicators for underlying pathology in healthy controls. Of course, the focus in this study has been on the biomarker relationships with attentional performance at the level of within-person variability, and not at the level of the sensitivity of the tasks themselves (e.g., congruency effects in RTs and errors in Stroop and Simon). In this light, it is important to note that in the current sample of healthy older adults, the congruency effects in errors in Stroop and the switching task are both correlated with the ptau181/β42 ratios, \(r = +.23, p < .05\), and \(r = +.25, p < .03\), respectively. Moreover, if one only considers the ε4+ individuals \((n = 26)\), even the congruency effect sizes in the Simon task are also correlated with the ptau181/β42 ratio in RTs, \(r = +.41, p = .03\). Thus, effect sizes in these attention tasks may indeed be differentially sensitive to the underlying pathology identified by biomarkers.

At this point, it is important to note that numerous targeted analyses were conducted examining the relationships between ApoE status, CSF biomarkers, and variability across the attention tasks. Thus one might be concerned that some of these relationships simply reflect capitalizing on chance due to multiple comparisons. Although this is a possibility, the ApoE effect in Stroop and the correlations with CSF biomarkers are in the predicted directions and consistent with other literature and hence are at least suggestive of the utility of examining within-person variability as a marker for early stage DAT. Indeed, although there were multiple-reliable correlations in the predicted direction, there were no reliable correlations in the unpredicted direction. Clearly, further research is warranted and we are currently increasing our sample sizes to further explore these interesting relationships.

Possible Mechanisms

There are a number of potential mechanisms that could contribute to the observed changes in variability, including the speed of neural transmission, functioning of neurotransmitter systems, synchronicity of neutral activity, fatigue, stress, practice/learning, among many others (see Hultsch et al., 2008). As suggested by Holtzer et al. (2008), the increase in between-task intraindividual variability, which we also obtained in our study, may indicate an early decline in global cerebral integrity representing different sensitivities of numerous brain regions to the disease process rather than the disease’s effect on a single brain region. Thus, it is likely that many of these mechanisms are intertwined. In addition

\(^3\) Indeed the correlations with these CSF biomarkers are present in a different version of the switching task with this participant sample.
to these neural accounts, at a higher cognitive level, we believe that the increase in variability in early stage DAT and in individuals at risk for developing DAT is consistent within an attentional control framework (see Balota & Faust, 2001; Faust & Balota, 2007). Specifically, a major goal of the human cognitive system is to flexibly tune itself to current task demands and stay tuned to such demands across time. Indeed, it is the flexibility of the cognitive system that likely reflects current notions of executive/attentional control (see, e.g., Baddeley, Chincotta, & Adlam, 2001; Engle & Kane, 2004). As attentional control systems begin to deteriorate, these systems are no longer consistently tuned across time to the specific goals of the task. Hence, there is an increase in variability and indeed this variability in performance may serve as an additional antecedent marker for DAT. Of course, as noted earlier, it is unlikely that there will be one mechanistic explanation for such a pattern. It is much more likely that one will need multiple descriptions at multiple levels. In this light, the present work is a first step in attempting to integrate work on intraindividual variability across the wide range of domains of attention, healthy aging, DAT, genotype, and biomarkers for DAT.

Conclusions
In sum, the current study supports the utility of examining intraindividual variability as a discriminator of healthy aging and early stage DAT and a potential early marker for the onset of the disease in healthy individuals (also see, Hultsch et al., 2008). Of course, how well such variability actually predicts conversion to early stage DAT depends on a large scale longitudinal study of well-characterized healthy controls, which is currently underway. Finally, we argue that the clear increase in trial-to-trial variability in early stage DAT is consistent with the notion of a breakdown in attentional control systems very early in the disease process.

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International Perspectives in Psychology: Research, Practice, Consultation

The Publications and Communications (P&C) Board of the American Psychological Association and Division 52 (International Psychology) of the APA have opened nominations for the editorship of International Perspectives in Psychology: Research, Practice, Consultation, for the years 2011–2016. The editor search committee is co-chaired by Lynn Collins, PhD, and Peter Ornstein, PhD.

International Perspectives in Psychology: Research, Practice, Consultation, to begin publishing in 2011, is committed to publishing conceptual models, investigative methodologies, and intervention strategies to help understand, study, and influence the world’s major mental health problems. The journal will promote psychological science and practice that is contextually informed, culturally inclusive and serves the public interest. Recognizing that mental health problems are imbedded in economic, environmental, political, and social contexts, International Perspectives in Psychology is a multidisciplinary title that will incorporate empirical findings from education, medicine, public health, applied and basic psychology, sociology and other related disciplines.

Included in the global concerns that interest the journal are inter-group conflict, societal transformations and national development, threats to the natural environment and recovery from national disasters, mental health care delivery and capacity buildings, and the struggles and physical and mental health needs of disempowered groups.

Editorial candidates should be available to start receiving manuscripts in July 2010 to prepare for issues published in 2011. Please note that the P&C Board encourages participation by members of underrepresented groups in the publication process and would particularly welcome such nominees. Self-nominations are also encouraged.

Candidates should be nominated by accessing APA’s EditorQuest site on the Web. Using your Web browser, go to http://editorquest.apa.org. On the Home menu on the left, find “Guests.” Next, click on the link “Submit a Nomination,” enter your nominee’s information, and click “Submit.” Prepared statements of one page or less in support of a nominee can also be submitted by e-mail to Molly Douglas-Fujimoto, Managing Director, Education Publishing Foundation, at mdouglas-fujimoto@apa.org.

Deadline for accepting nominations is January 31, 2010, when reviews will begin.

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