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Intraindividual variability in cognitive performance in three groups of older adults: Cross-domain links to physical status and self-perceived affect and beliefs

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Abstract

Intraindividual variability of physical status and affect/beliefs as well as their relations with cognition were examined in 3 groups of older adults: healthy elderly, individuals with a nonneurological health-related disturbance (arthritis) and people with neurological compromise (dementia). The findings showed that greater inconsistency in physical performance was observed in groups characterized by central nervous system dysfunction. By contrast, fluctuations in affect appeared to reflect other more transient sources, such as pain. In general, increased inconsistency in non-cognitive domains was associated with poorer cognitive function. There were cross-domain links between inconsistency in physical functioning and fluctuations in cognitive performance, although the nature of the links depended largely upon the neurological status of the individuals. Considered together, the result indicated that measures of cognitive as well as physical variability are important behavioral markers of neurological integrity. (*JINS*, 2002, *8*, 893–906.)

Keywords: Intraindividual variability, Inconsistency, Dementia, Physical variability, Cognitive variability, Cognition, Physiological function, Affect, Memory beliefs

INTRODUCTION

As early as 1926, Henry Head proposed that "an inconsistent response is one of the most striking results produced by a lesion of the cerebral cortex." A number of investigators (e.g., Benton & Blackburn, 1957; Goldstein, 1942) considered this phenomenon in subsequent years. However, researchers have only recently begun to explore more systematically the possibility that inconsistent performance within a task on a single occasion, or for the same task administered on multiple occasions over a short interval, represents a behavioral marker of underlying central nervous system dysfunction (Hendrickson, 1982; Li & Lindenberger, 1999).

The available literature suggests that increased intraindividual variability is observed in some "at-risk" groups, at least for some tasks. For example, several studies have shown that intraindividual variability across trials on reaction time (RT) tasks increases with age (Anstey, 1999; Fozard et al., 1994; Salthouse, 1993; West et al., in press). Hultsch et al. (in press) have recently reported that this age-related increase in inconsistency is independent of age group differences in overall slowing and is uniquely predictive of performance on other cognitive tasks. In addition to inconsistency across trials within a session, intraindividual variability may be observed across multiple testing sessions administered over relatively short intervals. Li et al. (2001) examined intraindividual variability for a set of memory and physical (gait) variables across 13 biweekly sessions in a sample of 24 older adults aged 64 to 86 years. They found that variability was positively correlated with age for most of the physical measures and one of the memory measures. West et al. (in press) found an age-related increase in variability in response latency both within and across four test occasions, but only on tasks requiring recruitment of executive control processes.

Greater intraindividual variability has also been associated with a variety of neurological conditions. For example, Benton and Blackburn (1957) reported that a group of brain-

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damaged individuals, most with vascular disease or neoplasm, showed a significant increase in intraindividual variability in simple, but not choice, RT with continued practice in comparison to patient controls. Bruhn and Parsons (1977) also found greater intraindividual variability across RT trials in people with epilepsy and individuals suffering from unspecified types of brain damage in comparison to controls. More recently, several studies by Stuss and his colleagues (Hetherington et al., 1996; Stuss et al., 1994, 1989) have noted increased intraindividual variability in persons with traumatic brain injury (TBI), at least for some reaction-time tasks and at some points in the recovery process. Collins and Long (1996) reported increased intraindividual variability across trials in simple and choice RT tasks in people who had suffered a TBI, even though they were not impaired in their standard neuropsychological test performance (as assessed by the Impairment Index of the Halstead-Reitan Neuropsychological Test Battery). Similarly, Bleiberg et al. (1997) used a computerized assessment battery and found individuals with TBI to be more erratic in their across-day performance.

Increased intraindividual variability also appears to be characteristic of persons diagnosed with dementia. For example, Knotek et al. (1990) examined mildly and moderately impaired patients with probable Alzheimer's disease (AD) as well as healthy individuals on a picture-naming task. Each individual was tested twice with a 7-day intertest interval. They found that the AD patients responded less consistently to the items than did the normal participants. Moreover, the moderately impaired AD patients had a higher rate of response inconsistency than the mildly impaired AD individuals. Recent findings from our own laboratory also suggest greater intraindividual variability in patients diagnosed with mild dementia, most with a clinical diagnosis of probable AD (Hultsch et al., 2000). We contrasted these individuals with healthy controls and with neurologically intact individuals who were suffering significant somatic disturbance (arthritis) on a number of reaction time and episodic memory tests. Individuals with dementia showed increased intraindividual variability in latency both within and across four weekly test sessions relative to the adults who were neurologically intact, regardless of their health status. Further, intraindividual variability was related to level of performance on other cognitive tasks and was uniquely predictive of neurological status independent of level of performance. The implication is that short-term intraindividual variability in cognitive performance is a stable trait of individuals, evident both within and across test sessions and reflects primarily a central nervous system phenomenon rather than general health-related conditions.

To date, most of the modest number of studies examining intraindividual variability have focused on the cognitive domain. To the extent that inconsistency represents a behavioral marker of neurobiological functioning (e.g., Bruhn & Parsons, 1977; Jensen, 1992; Li et al., 2001; Li & Lindenberger, 1999), at-risk populations should exhibit greater intraindividual variability in physical functioning as well as cognitive performance compared to healthy individuals. Moreover, we would expect positive relationships among measures of inconsistency across these two domains and that variability in one domain (e.g., physical function) would be related to level of performance in another (e.g., cognition).

There are some hints that this is the case. For instance, Ferrandez et al. (1996) reported that older adults showed greater intraindividual variability in gait than younger individuals, even when walking slowly. Similarly, Nakamura et al. (1996), studying individuals diagnosed with probable AD, found that variability in gait (stride length) increased with severity of dementia and was related to reduction of regional cerebral blood flow in the frontal lobe and basal ganglia as the disease progressed. Goldstein et al. (1998) reported that elevated blood pressure (BP) level and variability in particular, were associated with difficulties in attention and short-term/working memory in healthy elderly individuals. Goldstein et al. (1998) also found greater BP variability during waking in individuals with increased white matter hyperintensities of the brain. Recently, Li et al. (2001) found that intraindividual fluctuation in sensorimotor performance (gait) over occasions was a relatively stable attribute of persons. In addition, such inconsistency was correlated positively with age and negatively with memory for spatial locations and stories in their older adult sample. They suggested that this combination of results is consistent with the view that there is a common cause contributing to the disturbances in both cognitive and non-cognitive domains (e.g., Baltes & Lindenberger, 1997).

In addition to the link between variability in physical performance and cognitive functioning, it is also possible that there may be other cross-domain connections, particularly in at-risk populations. For example, Montgomery (1995) suggested that performance inconsistency associated with brain injury may be a function of both endogenous and exogenous factors. Thus, intraindividual variability may only partly be a reflection of internal neurobiological mechanisms such as damage to neural structures or disruptions in neurotransmitter systems. Fluctuations in cognitive performance may also be associated with shifts in affect, perceived competence, stress, fatigue, pain or other states that are perhaps more dependent on external environmental conditions than on internal biologically based mechanisms. Moreover, Montgomery (1995) noted that cognitive, physical, and emotional mechanisms may interact with one another. For example, poor or inconsistent cognitive performance may elicit affective responses which then further interfere with cognitive functioning.

Our previous research (Hultsch et al., 2000) pointed to the importance of neurological status rather than presence of somatic disturbance as predictive of intraindividual variability in cognitive performance. Individuals diagnosed with mild dementia showed greater inconsistency on cognitive tasks relative to neurologically intact adults, regardless of whether they were healthy or experiencing significant pain associated with arthritis. The current study examines the same individuals, but focuses on cross-domain linkages be-

tween intraindividual variability in physical performance and self-perceived affect and beliefs on the one hand and cognitive performance on the other. Examination of multiple cross-domain linkages simultaneously will help to shed light on the hypothesis that measures of intraindividual variability are unique indicators of central nervous system compromise. To the extent that inconsistency in cognitive performance is a function of brain-based endogenous mechanisms, it should be more strongly associated with variability in physical performance than with variability in more situationally determined affective states or beliefs.

The present study sought to answer the following five questions. First, are there group differences in intraindividual variability on measures of physical performance and self-perceived affect and beliefs? More specifically, are individuals diagnosed with a neurological disturbance (dementia) more variable across a variety of measures of physical status (e.g., gait, blood pressure, manual ability, cardiovascular fitness) and affective state/self-beliefs (e.g., mood, perceived competence and control)? Second, what are the relations between fluctuations in one domain (e.g., physical status or mood state) and mean level of performance in another domain (e.g., speed and accuracy on cognitive tasks)? Recent findings (e.g., Goldstein et al., 1998; Li et al., 2001) lead us to expect that inconsistency in noncognitive domains (physical function in particular) signifies cognitive impairment. Third, are there significant relationships between variability in one domain (e.g., cognitive performance) and variability in another domain (e.g., physical abilities) as others have suggested (e.g., Li et al., 2001)? Is such a relation specific to neurological compromise or is this a more general phenomenon? Fourth, is cognitive performance predicted better by fluctuations in physical or affect/belief variables? Finally, do measures of noncognitive variability provide information that uniquely differentiates neurologically intact from impaired individuals?

METHODS

Research Participants

The participants consisted of 45 adults (27 women and 18 men) ranging in age from 57 to 87 years of age who were divided into three groups on the basis of health status. The first group consisted of 13 individuals diagnosed by their physician as having mild dementia. Ten of these participants met NINCDS-ADRDA diagnostic criteria for possible or probable Alzheimer's disease (McKhann et al., 1984) and the remaining three participants were diagnosed with vascular dementia. The second group consisted of 17 neurologically normal individuals who reported experiencing osteoarthritis and accompanying levels of pain that interfered with their daily activity. Finally, the third group consisted of 15 healthy adults. Exclusionary criteria for all groups included a history of significant head injury (defined as loss of consciousness for more than 5 min), other neurological or major medical illnesses (e.g., Parkinson's disease, heart disease, cancer), severe sensory impairment, extensive drug or alcohol abuse, inpatient psychiatric treatment, or a Mini Mental Status Examination (MMSE; Folstein et al., 1975) score less than 18 (dementia group) or 26 (arthritic and healthy groups). All participants resided in the community. Participants diagnosed with mild dementia were recruited from neurological and geriatric services. The healthy adults and individuals with arthritis were recruited through newspaper and radio advertisements.

Participants provided demographic and self-reported health information during an initial intake interview. In addition, several benchmark cognitive measures were obtained during this session including the MMSE, the Wechsler Adult Intelligence Scale–III (WAIS–III) Block Design and Vocabulary subtests (Psychological Corporation, 1997), and the North American Adult Reading Test (NAART; Blair & Spreen, 1989). We also computed estimates of age-adjusted Full-Scale IQ (FSIQ) based on the Block Design and Vocabulary subtests (Sattler & Ryan, 1999), and premorbid IQ based on the NAART (Blair & Spreen, 1989).[1]

Table 1 shows the age, education, self-reported health, and benchmark cognitive status of the participants as a function of group. Significant overall differences ($p < .05$) among the groups were observed for all of the variables except age and illness episodes: education [$F(2,42) = 4.21$, $\eta^2 = .17$]; chronic illness [$F(2,42) = 6.09$, $\eta^2 = .23$]; pain [$F(2,42) = 6.78$, $\eta^2 = .24$]; MMSE [$F(2,42) = 22.68$, $\eta^2 = .52$]; Block Design [$F(2,42) = 19.11$, $\eta^2 = .48$]; Vocabulary [$F(2,42) = 25.67$, $\eta^2 = .55$]; estimated FSIQ [$F(2,42) = 42.28$, $\eta^2 = .67$]; NAART and estimated NAART IQ [$F(2,42) = 6.33$, $\eta^2 = .23$]. *Post-hoc* contrasts using Tukey's HSD ($p < .05$) indicated that the effect for education was the result of a significant difference between the healthy and dementia groups. The arthritic group reported more chronic illnesses than the dementia group and more pain than both the healthy and dementia groups which did not differ. For the cognitive benchmark variables, all of the significant effects were the result of the poorer performance of the dementia group compared to the arthritic and healthy groups which did not differ. The differences among the groups in chronic illness, pain, and cognitive status are to be expected given their composition. However, the lower level of education of the participants in the dementia group is potentially problematic to the extent that education is correlated with our measures of interest. We address this issue further in the Results section.

Procedure

Following the intake interview, the primary data collection occurred over four separate sessions. Participants were tested

[1]Blair and Spreen's (1989) formula for estimating premorbid intellectual ability using the NAART is $NAART_{estIQ} = 127.8 - .78\,(NAART_{errors})$. This formula is based on the WAIS–R, whereas our estimate of current IQ is based on the WAIS–III which is somewhat more difficult. Thus, the discrepancy between the NAART estimate and the WAIS–III estimate will, if anything, slightly overestimate cognitive decline.

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Table 1. Demographic and performance characteristics as a function of group

Variable	Group		
	Healthy *M* (*SD*)	Arthritic *M* (*SD*)	Dementia *M* (*SD*)
Age	75.00 (5.01)	76.00 (6.44)	76.15 (7.48)
Years of education	15.00 (2.73)	14.35 (2.47)	12.15 (2.94)
Chronic illness	3.60 (2.61)	5.29 (1.96)	2.62 (1.71)
Pain	4.02 (4.28)	8.13 (2.95)	4.13 (3.47)
Illness episodes	7.27 (7.64)	10.65 (7.01)	7.31 (5.14)
MMSE	28.93 (1.03)	29.00 (1.22)	25.00 (2.83)
Letter fluency	15.93 (2.94)	14.65 (5.02)	8.62 (3.93)
WAIS Digit Symbol	39.13 (9.93)	35.76 (7.85)	16.92 (9.01)
WAIS Block Design	37.73 (8.86)	34.00 (7.01)	20.23 (7.55)
WAIS Vocabulary	55.87 (6.28)	54.65 (8.12)	33.15 (13.18)
Estimated WAIS FSIQ	122.13 (8.80)	118.18 (7.68)	90.38 (13.16)
NAART	14.07 (6.35)	15.82 (7.18)	27.31 (16.68)
Estimated NAART IQ	116.83 (4.95)	115.46 (5.60)	106.50 (13.01)

Note. Chronic illness consists of self-reported presence of up to 16 chronic conditions during the past year. Pain represents self-reported level of pain experienced during the past week on a scale of zero to 20. Illness episodes consists of the number of self-reported visits to a physician during the past year.

weekly on a battery of cognitive tasks and indicators of physical and emotional functioning. Most participants were tested in their own homes, but a few individuals were tested at the university. Because of scheduling conflicts and holidays, 5 weeks were required to obtain the four measurements. Rather than being separated by exactly 1 week, an effort was made to distribute the testing sessions across days of the week and time of day (morning/afternoon). Sessions were scheduled no closer than 2 days and no further than 9 days apart. Within these constraints, the time of testing was distributed across possible days/times to the extent permitted by the individual's schedule. Participants within all groups were tested at irregular intervals in order to avoid any systematic effects associated with particular days and time.

Cognitive Measures

The cognitive measures consisted of four tasks: two basic reaction time tasks and two more complex recognition memory tasks. All of the tasks were administered on a laptop computer, and measures of both latency (in ms) and accuracy (% correct) were obtained. Four alternate versions of each memory task were developed to minimize specific practice effects across occasions. Tasks were administered in a constant order across the four sessions. A traditional measure of trait reliability was obtained by calculating the intraclass correlation for each measure across the four sessions.

Reaction time

Simple reaction time (SRT) and two-choice reaction time (CRT) tasks were administered. The instructions emphasized speed of performance. In SRT, participants were presented with a warning stimulus followed by a signal stimulus 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 five intervals separating the warning and signal stimuli (500, 625, 750, 875, and 1000 ms). The measures used were the mean latencies of the 50 test trials (no accuracy score is available). Estimated reliability for this task based on the intraclass correlation was .81.

For CRT, participants received a warning signal consisting of two crosses presented to the left and right of the center of the screen. After a delay of 1000 ms, one of the crosses changed into a square. The location of the square was randomly equalized across trials. Participants were instructed to press a key corresponding to the location of the square as quickly as possible. A total of 10 practice trials followed by 50 test trials were administered. The measures used were the mean latencies and percent correct for the 50 test trials. Estimated reliabilities for this task based on the intraclass correlation were .79 (latency) and .71 (accuracy).

Episodic memory

Word and story recognition tasks were used. The instructions for these tasks emphasized accuracy. The word recognition task was based on prior exposure to an uncategorized list of 12 English words. Approximately 15 min after hearing and recalling the 12-word list, participants were presented with a list of 24 words consisting of the 12 previously presented words and 12 new words. The words were presented one at a time on the computer screen, and participants were asked to press one of two keys to indicate whether

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the word was old (on the previously presented list) or new (not on the previously presented list). Four lists with equivalent word characteristics and connectivity were developed. Words varied in length from four to nine letters and all were above average in rated concreteness and imagery (Pavio et al., 1968). The measures used consisted of the mean latency for the trials and the number of items correctly completed. Estimated reliabilities for this task based on the intraclass correlation were .85 (latency) and .57 (accuracy).

Story recognition was based on four narrative stories selected from a set of 25 structurally equivalent texts developed by Dixon et al. (1989). Each story was approximately 300 words and 160 propositions long and related events in the life (lives) of older adults. The stories were recorded on audio tape by a male professional actor. Immediately following presentation of the story, 24 statements about the story were presented one at a time on the computer screen. Participants were asked to press one of two keys to indicate whether each statement represented an idea that was contained in the story (statements presenting a correct idea from the story), or an idea that was not contained in the story (statements presenting an incorrect idea from the story, and ideas consistent with the theme of the story that were not mentioned). There were eight statements of each type. The measures used consisted of the mean latency for the trials and the number of items correctly completed. Estimated reliabilities for this task based on the intraclass correlation were .86 (latency) and .75 (accuracy).

Physical Measures

Physical performance was assessed by measures of balance/gait, fine motor dexterity, blood pressure, and respiratory function. These measures were administered prior to the cognitive tasks. Order of administration was held constant across the four test sessions.

Turn 360 task

This measure of balance/gait evaluated the number of steps required to turn 360° and return to the starting position.

Finger dexterity (dominant and nondominant)

Fine motor dexterity was tested separately for each hand by having the person touch each of the fingers to their thumb beginning with the little finger. The time to complete three entire sequences was recorded for each hand.

Blood pressure

Systolic and diastolic blood pressure were measured using an electronic, automatic monitor (Omron). The measures were taken once each session from above the elbow of the right arm with the individual seated. Participants had been seated for about 10 min when these measures were obtained.

Peak expiratory flow

The participant was asked to blow as hard as possible into the mouthpiece of a peak flow meter. The volumes of three successive attempts were averaged and used as the measure.

Self-Perceived Affect and Beliefs

Measures of positive and negative affect and self-perceived competence and control were administered at each of the four occasions. These measures were administered prior to the cognitive tasks in a constant order.

Positive and negative affect schedule (PANAS)

This questionnaire (Watson et al., 1988) required participants to rate 10 positive and 10 negative affect descriptors (e.g., *proud*, *hostile*) on a 5-point scale asking how they felt "right now." Internal consistency and test–retest reliability are reported to be high for each scale. The two scales (positive and negative affect) are largely independent of each other and appear to be sensitive to fluctuations in mood (Watson et al., 1988).

Perceived competence and control

Scales of perceived competence (individual's perception of his or her ability to perform actions necessary to achieve desired outcomes) and locus of control (individual's beliefs about whether outcomes are contingent on his or her actions rather than chance, fate, or powerful others) from Eizenman et al. (1997) were used. Participants were asked to respond to eight items (four for competence and four for control) on a 7-point adjective-anchored rating scale (from 1–7) according to how they felt now. Higher scores indicated greater perceived competence and control. Eizenman et al. have reported the items show good test–retest reliability. Confirmatory factor analysis showed invariance of the two-factor model across multiple occasions of measurement spanning 25 weeks.

RESULTS

Our earlier study (Hultsch et al., 2000) considered average level and intraindividual variability in cognitive performance in three groups of older adults (healthy, arthritic, demented). In the current study, we focus on the relations between cognitive performance (both level and variability) on the one hand and physical performance and affect/belief status on the other. The results are presented in five main parts corresponding to our questions raised earlier. First, we compared average level of performance for each of the measures of physical status and of affect and beliefs across groups and occasions. The second set of analyses focused on the issue of group differences in intraindividual variability across the four occasions for the measures of physical and affective/belief status. Third, we computed correlations examining relations among measures of intra-

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Table 2. Mean affect, physical, and cognitive performance as a function of group

Variables	Group		
	Healthy *M* (*SD*)	Arthritic *M* (*SD*)	Dementia *M* (*SD*)
Physical			
Systolic BP	134.85 (14.94)	136.83 (15.14)	135.48 (14.71)
Diastolic BP	78.94 (13.68)	79.39 (9.54)	82.60 (18.80)
Turn 360°	*5.71* (*1.01*)	*6.59* (*.76*)	*6.59* (*1.27*)
Finger dexterity (dominant)	442.41 (91.10)	473.29 (119.21)	524.66 (110.91)
Finger dexterity (nondominant)	*413.74* (*52.77*)	*448.80* (*124.55*)	*572.64* (*206.17*)
Peak expiratory flow	375.88 (120.93)	300.76 (115.08)	292.49 (119.69)
Affect/beliefs			
Positive affect	*3.70* (*.58*)	*3.10* (*.70*)	*3.10* (*.55*)
Negative affect	1.20 (.23)	1.21 (.26)	1.13 (.14)
Locus of control	*5.85* (*.99*)	*5.11* (*.89*)	*5.17* (*.67*)
Efficacy	*5.88* (*.74*)	*5.10* (*.98*)	*5.45* (*.65*)
Cognitive			
SRT latency	*360.14* (*31.63*)	*440.96* (*97.21*)	*480.72* (*129.89*)
CRT latency	*483.20* (*69.79*)	*518.23* (*94.30*)	*664.73* (*176.79*)
Word latency	*1522.41* (*193.10*)	*1556.46* (*280.11*)	*3115.21* (*989.26*)
Story latency	*4033.75* (*709.32*)	*4098.40* (*754.71*)	*7567.52* (*1437.24*)
CRT accuracy	49.85 (.17)	49.38 (1.66)	48.39 (3.84)
Word accuracy	*19.00* (*1.73*)	*18.92* (*2.16*)	*14.50* (*2.08*)
Story accuracy	*20.54* (*1.94*)	*20.41* (*1.98*)	*15.74* (*3.12*)

Note. Values in italics indicates significant group differences.

individual variability and among measures of intraindividual variability and level of cognitive performance (latency as well as accuracy). Fourth, we used partial set correlation (Cohen, 1982) to evaluate whether level of cognitive performance is predicted better by fluctuations in physical or affect/belief variables. Finally, we used discriminant function analysis to address the question of whether measures of noncognitive variability provide information that uniquely differentiates neurologically intact from impaired individuals. For all tests of statistical significance, we used a $p <$ .05 alpha criterion.

Group Differences in Level of Performance Across Occasions[2]

We began with an examination of overall level of physical performance and affect/belief. If differences in physical performance and/or affect/beliefs emerge as a function of group, occasion and possibly their interaction, then it is necessary to purify the data of any systematic effects. Intraindividual variability refers to within-person variation that is independent of relatively durable changes (e.g., practice effects) over time. Because we are not interested in these systematic changes, any effects associated with occasions must be removed statistically prior to analysis. Moreover, group differences in performance or self-report must also be removed statistically in order to insure that group differences in intraindividual variability are not simply an artifact of average differences in ability or affect and beliefs.

For the initial analyses, we examined the raw scores for each of the physical and affect/belief variables. Separate Group × Occasion ANOVAs, with group as a between-subjects factor and occasion varying within subjects, were performed on each of the measures. The mean scores for the three groups are shown in Table 2.[3]

The analyses of the physical scores indicated that there were significant main effects associated with group, occasion and Group × Occasion for some of the measures. Group differences emerged on the nondominant finger-dexterity task [$F(2,41) = 4.85$, $\eta^2 = .19$]. Participants with dementia were considerably slower than healthy and arthritic individuals who did not differ. The occasion [$F(3,123) = 5.92$, $\eta^2 = .13$] and Group × Occasion effects [$F(6,123) = 3.68$, $\eta^2 = .15$] were also significant and indicated that between-group differences emerged on this task on all but the last test occasion. There was also a significant group effect for the Turn task [$F(2,31) = 3.61$, $\eta^2 = .15$]. Healthy individuals took fewer steps than participants with dementia or arthritis. Occasion effects also emerged on the Turn

[2]One individual in the healthy elderly group was omitted from further analyses because his scores were generally 3 *SD*s greater than his own group's means.

[3]Table 2 also shows the mean raw latency and accuracy scores for the cognitive tasks. Analyses of these scores were provided in Hultsch et al. (2000). In general, participants with dementia were slower and less accurate than the healthy and arthritic individuals who did not differ from one another.

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task [$F(3,123) = 8.85$, $\eta^2 = .18$] and the measure of peak expiratory flow [$F(3,123) = 2.11$, $\eta^2 = .07$]. With practice, the number of steps required to turn 360° declined, whereas the mean cardiovascular output increased.

The analyses of the affect/belief measures indicated that the groups differed in terms of their rating of positive affect [$F(2,41) = 4.38$, $\eta^2 = .18$]. Healthy individuals rated their mood more positively than the patient groups. In addition, the groups differed in their ratings of control [$F(2,41) = 3.24$, $\eta^2 = .14$] and efficacy [$F(2,41) = 3.43$, $\eta^2 = 14$]. Healthy individuals perceived themselves as having greater control and competence than individuals with arthritis. There were no additional significant main effects or interactions.

As noted previously, there were significant group differences in education. However, when the entire sample was considered, education was not correlated with the physical or affective measures.

The significant differences revealed in the analyses of average raw physical and affect/belief scores were consistent with our expectations of slower performance for individuals diagnosed with dementia, as well as of more positive mood among healthy participants. In addition, there were systematic changes across the four sessions associated with practice. Because these systematic effects represent potential confounds for the analysis of intraindividual variability, we analyzed the residuals from the Group × Occasion mixed-model ANOVA. This procedure produced residual scores that were uncontaminated by group differences in physical ability or affect/belief. In addition, this procedure partialed *all* systematic trends (e.g., linear, quadratic, and cubic) across occasions due to influences such as practice and learning to learn as well as all groups by trends effects. These purified scores were then converted to *T* scores to permit comparison of the tasks in the same metric.

Group Differences in Intraindividual Variability

There are many indices that may be computed to examine intraindividual variability (Slifkin & Newell, 1998). Perhaps the simplest of these is the intraindividual standard deviation (ISD). We computed ISDs on the physical performance and affect/belief purified scores for each individual across the four occasions. We also computed the coefficient of variation (CV) in which each individual's ISD is divided by their own mean score. This provides a measure of intraindividual variability relative to the individual's level of physical performance and affect/belief status.

For these analyses, we used ANOVA with follow-up contrasts on group effects. Significant group effects ($p < .05$) were examined by contrasts ($p < .05$) comparing (1) the two neurologically intact groups (healthy and arthritic) with the dementia group; and (2) the healthy and arthritic groups. Table 3 presents the mean ISDs for the various physical,

Table 3. Mean intraindividual variability of physical, affect/belief, and cognitive variables as a function of group

	Group		
Variables	Healthy *M* (*SD*)	Arthritic *M* (*SD*)	Dementia *M* (*SD*)
Physical			
Systolic BP	6.06 (3.89)	5.01 (2.67)	4.81 (3.09)
Diastolic BP	3.94 (3.13)	3.65 (2.18)	5.57 (5.57)
Turn 360°	3.60 (1.33)	4.38 (2.35)	4.01 (2.21)
Finger dexterity (dominant)	6.96 (7.65)	4.57 (2.41)	6.42 (2.68)
Finger dexterity (nondominant)	*2.67* (*1.39*)	*3.43* (*1.86*)	*8.63* (*4.80*)
Peak expiratory flow	2.32 (1.89)	2.47 (1.75)	2.12 (1.13)
Affect/beliefs			
Positive affect	*3.93* (*2.51*)	*7.19* (*3.61*)	*3.10* (*1.56*)
Negative affect	5.96 (7.05)	6.65 (6.61)	3.78 (4.01)
Locus of control	*3.94* (*2.63*)	*6.10* (*2.72*)	*6.30* (*2.87*)
Efficacy	5.90 (3.14)	6.57 (3.15)	5.46 (2.60)
Cognitive			
SRT latency	*1.78* (*.73*)	*2.41* (*1.45*)	*4.34* (*2.69*)
CRT latency	*1.48* (*.64*)	*2.13* (*1.23*)	*4.87* (*2.73*)
Word latency	*1.50* (*.56*)	*1.74* (*.68*)	*4.88* (*2.40*)
Story latency	*1.55* (*.95*)	*2.38* (*1.17*)	*5.53* (*2.52*)
CRT accuracy	.90 (.83)	5.47 (10.10)	4.01 (4.25)
Word accuracy	5.78 (2.77)	7.56 (4.01)	7.07 (3.71)
Story accuracy	*5.21* (*2.12*)	*5.23* (*1.70*)	*7.47* (*3.51*)

Note. Values in italics indicate significant group differences.

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Table 4. Correlations between cognitive performance (latency and accuracy) and variability in physical/affective status

	Mean latency				Mean accuracy		
	SRT	CRT	Word	Story	CRT	Word	Story
Variability in physical status							
Systolic BP	−.19	−.09	.09	−.01	.05	−.07	−.02
Diastolic BP	.03	.10	.17	.23	−.01	−.*35*	−.*32*
Turn 360°	.08	.12	.03	.11	.07	−.14	−.12
Finger dexterity (dominant)	.06	.22	.13	.14	.01	−.12	−.25
Finger dexterity (nondominant)	.*33*	.*35*	.*67*	.*61*	−.13	−.*64*	−.*49*
Peak expiratory flow	−.18	−.17	−.05	−.07	.07	.08	.01
Variability in affect/beliefs							
Positive affect	−.14	−.29	−.*33*	−.*41*	.01	.22	.*30*
Negative affect	−.04	−.14	−.19	−.21	−.28	.01	−.04
Locus of control	.29	.*35*	.*35*	.25	−.22	−.27	−.09
Efficacy	−.05	−.06	.04	−.10	−.03	−.02	.10

Note. According to Cohen (1977), correlations of .30–.50 are considered moderate in size and those above .50 are viewed as large. In order to protect against excessive Type 1 errors, in the context of a relatively small sample, correlations above .30 were regarded as noteworthy. In addition, all correlations with an absolute magnitude greater than .30 were significant (two-tailed $p < .05$) in our study.

affect/belief and cognitive variables for each group.[4] ANOVA conducted on the ISD scores revealed significant group differences (i.e., group differences still existed in the variability of the residuals independent of the systematic group differences that were purified) in nondominant finger dexterity [$F(2,41) = 16.41$, $\eta^2 = .45$], positive affect [$F(2,41) = 9.27$, $\eta^2 = .31$], and locus of control [$F(2,41) = 3.25$, $\eta^2 = .14$]. Participants with dementia were more variable when required to rapidly produce a finger sequence with their nondominant hand whereas individuals with arthritis were more variable in their ratings of positive mood. Analyses using the CV and covarying education yielded the same results. With regard to perceived control, healthy individuals were less variable than patients but the effect disappeared when education was used as a covariate or CV was used as the index of intraindividual variability.

In short, the results only partially conformed to expectation. Inconsistency appears not to be a uniform phenomenon. Although fluctuations in physical function appear suggestive of central nervous system compromise, shifts in affect, at least of positive mood, seem to reflect other mechanisms such as the experience of pain.

Correlational Analyses Between Cognition and Physical/Affective Status

We next performed a series of correlational analyses to examine (1) relationships between mean level of speed and accuracy in cognitive performance and variability in physical/mood states and, (2) relationships among the various measures of intraindividual variability.

Intercorrelations between mean level of cognitive performance and variability

The intercorrelations were computed between level of cognitive performance indicated by the average across occasion latency and accuracy scores and the across-occasion ISDs for each of the physical and affect/belief variables. These correlations are shown in Table 4.

Individuals who were less accurate on word and story recognition tasks varied more in their diastolic blood pressure. Similarly, people who made more errors on the word and story recognition tests fluctuated more in their nondominant fingertapping speed. In addition, those who were slower in responding on the various cognitive tasks (SRT, CRT, Word, Story) varied more in nondominant fingertapping speed.

Increased variability in ratings of positive affect was linked to slowed (Word, Story) but more accurate (Story) memory performance. Individuals who were slower in responding on various cognitive tasks (CRT, Word) fluctuated more in their sense of control. Finally, poor cognitive performance was also related to variability in ratings of negative affect although the precise pattern of cross-domain relations depended upon the group examined. Thus, significant interactions with group emerged on the word recognition [$F(2,38) = 3.67$] and CRT [$F(2,38) = 29.80$] tasks. As Table 5 shows, healthy people who were slow to respond on the word recognition task tended to be more inconsistent in their ratings of negative affect ($p < .10$). Participants with dementia who were less accurate on the CRT task fluctuated more in their negative ratings.

[4] Analyses of the cognitive measures are reported in Hultsch et al. (2000). Participants with dementia were more variable than healthy and arthritic individuals who did not differ from one another.

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Table 5. Correlations between variability in negative affect and level of cognitive performance as a function of group

	Group		
Variables	Healthy	Arthritic	Dementia
Word recognition RT			
Negative affect	*.47*	.11	−.42
CRT accuracy			
Negative affect	−.14	−.16	*−.90*

Thus, increased fluctuation in one domain was generally associated with a lower level of performance in another domain. Individuals who were slower and less accurate on measures of memory also varied more in their physical performance from week to week. Those with better memory fluctuated less physically. Further, people who were slower and more inaccurate on cognitive tasks shifted their self-perception (in particular, their perceived control and feelings of negative affect) more from week to week although the precise pattern of these cross-domain relations varied somewhat depending upon the health status of the individuals.

Cross-domain correlations between measures of intraindividual variability

The cross-domain relations between the measures of inconsistency are shown in Table 6. Increased variability on the nondominant finger-tapping task was linked to increased inconsistency in latency on the various cognitive tasks (SRT, Word, Story).

Individuals who fluctuated more in their diastolic blood pressure were also more variable with regard to their response latencies on the word and story recognition tasks. Similarly, individuals who were more variable in their gait were also more inconsistent in their speed of response on the word and story recognition tests. However, the relations between the measures of physical and cognitive variability were qualified by group membership. Thus, with respect to latency of response on the word recognition task, relations with systolic [$F(2,38) = 7.48$] and diastolic blood pressure [$F(2,38) = 5.04$], as well as gait [$F(2,38) = 9.20$], varied as a function of group status. Similarly, group differences emerged in the pattern of cross-domain relations between latency of response on the story recognition task and diastolic blood pressure [$F(2,38) = 4.17$], and gait [$F(2,38) = 5.00$]. Correlation coefficients presented in Table 7 show that intraindividual fluctuations in physical and cognitive variables were correlated highly but only for participants diagnosed with dementia.

Shifts in affect/beliefs were also related to variability in cognitive performance although the pattern of the cross-domain links was less uniform and tended to depend on the health status of the participants. As shown in Table 6, inconsistency in ratings of positive mood was associated with variability in response speed on the word recognition task. Group differences emerged in the pattern of cross-domain links between SRT latency and perceived control [$F(2,38) = 5.25$], and efficacy [$F(2,38) = 4.15$]. As Table 7 shows, increased inconsistency in SRT latency was associated with greater shifting in beliefs about self-control and efficacy, but only among the participants with dementia. Group differences were found between latency on the word recognition task and perceived control [$F(2,38) = 6.61$] and efficacy [$F(2,38) = 9.88$]. On this task, increased inconsistency in beliefs was linked to reduced variability in cognition, but only for healthy and demented participants. Finally, the relation between word recognition accuracy and perceived

Table 6. Correlations between variability in cognition and physical/affective status

	Variability in latency				Variability in accuracy		
	SRT	CRT	Word	Story	CRT	Word	Story
Variability in physical status							
Systolic BP	.01	.01	.12	−.01	−.04	−.16	.05
Diastolic BP	.02	.15	*.50*	*.40*	.04	.01	.09
Turn 360°	−.07	−.04	*.33*	*.32*	−.05	.17	−.10
Finger dexterity (dominant)	.11	.09	.04	−.06	−.10	−.06	.23
Finger dexterity (nondominant)	*.48*	.27	*.43*	*.39*	.04	−.01	.18
Peak expiratory flow	−.16	.02	−.11	−.12	.07	−.09	.02
Variability in affect/beliefs							
Positive affect	−.18	−.21	*−.32*	−.28	.21	.09	.03
Negative affect	−.06	−.09	−.23	−.24	.19	−.10	−.18
Locus of control	*.42*	.21	−.03	.01	.29	*.40*	−.18
Efficacy	.14	.04	−.23	−.24	.13	*.35*	−.11

Note. According to Cohen (1977), correlations of .30–.50 are considered moderate in size and those above .50 are viewed as large. In order to protect against excessive Type 1 errors, in the context of a relatively small sample, correlations above .30 were regarded as noteworthy. In addition, all correlations with an absolute magnitude greater than .30 were significant (two-tailed $p < .05$) in our study.

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Table 7. Cross-domain correlations between measures of variability as a function of group

Variables	Group		
	Healthy	Arthritic	Dementia
Story recognition RT			
Diastolic BP	−.02	.01	*.71*
Turn 360	.13	.35	*.75*
Word recognition RT			
Systolic BP	−.11	.04	*.63*
Diastolic BP	−.02	.01	*.71*
Turn 360	.13	.35	*.75*
Simple reaction time			
Locus of control	.16	.06	*.68*
Efficacy	.27	−.10	*.56*
Word recognition RT			
Locus of control	*−.56*	.42	*−.58*
Efficacy	−.10	.40	*−.65*
Word recognition accuracy			
Locus of control	−.32	*.69*	.42

Note. Values in italics indicate significant relations ($p < .05$).

control also differed as a function of group [$F(2,38) = 4.93$]. As shown in Table 7, increased variability in perceived control was related to increased variability in memory performance, but only among individuals with arthritis.

In short, the findings confirm that significant cross-domain relations exist with regard to variability. However, the nature of the relations depends upon the particular domains assessed, the measures used, and the health status of the individuals. Inconsistency in physical performance was linked to fluctuations in cognitive performance, but only when cognition was indexed by response speed and was most prominent among individuals with central nervous system dysfunction. Individuals with dementia who varied more in their beliefs about their own abilities were also more variable in their simple reaction time; however, the relations between fluctuations on the word recognition task and beliefs were more complex.

Predicting Cognitive Performance

In previous research (Hultsch et al., 2000), we demonstrated that intraindividual variability in cognitive performance uniquely accounted for a significant proportion of variance in cognition over and above mean-level influences. Having demonstrated the potential utility of intraindividual variability as an independent marker of cognitive function, a logical next step is to examine relative influences for distinct types of variability. Of particular interest in the present investigation is whether mean cognitive performance (both latency and accuracy) is better predicted by fluctuations in physical performance or affect/belief status. We used partial set correlation (covarying for group status) to examine unique and shared influences of intraindividual variability in physical performance and affect/belief status as predictors of cognition. Separate analyses were conducted for sets of latency (SRT, CRT, Word, and Story) and accuracy (CRT, Word, and Story) dependent measures. Given the large number of potential independent measures, the two best exemplars of intraindividual variability from physical performance (nondominant finger dexterity and Turn 360) and affect (locus of control and positive affect) were selected as predictors. Variance for both cognitive latency and accuracy was partitioned into that uniquely predicted by variability in physical function, variability in affect/belief status, as well as variability shared between these predictors. To derive these estimates, three set correlations were computed: regression of cognitive measures onto measures of variability without partialing any variables, regression of cognitive measures onto physical variability partialing affect/belief variability, and regression of cognitive measures onto affect/belief variability partialing physical variability.

Latency

As a group, performance latency in SRT, CRT, word, and story was significantly predicted by variability in both physical performance and affect [$F(16,110.6)$[5] $= 2.66$, multivariate $R^2 = .441$]. Table 8 outlines the amount of total variance in latency performance that is uniquely accounted for by variability in physical function and affect, as well as the variance shared between these predictors. Partial set correlation findings indicated that variability in physical function significantly predicted cognitive performance independent of variability in affect/belief status [$F(8,72) = 2.44$], adjusted multivariate partial $R^2 = .236$, but that variability in affect/beliefs did not significantly predict cognitive latency after partialing variability in physical function. Of the total variance accounted for by intraindividual variability in physical and affect/belief status, 53.5% was accounted for by variability in physical function, 22.0% was accounted for by variability in affect, with the remaining 24.5% of this variance shared between these two types of variability.

Accuracy

Accuracy in cognitive performance (CRT, Word, and Story) was also significantly predicted by variability in both physical performance and affect [$F(12,98.2) = 2.73$, multivariate $R^2 = .367$]. This variance predicted in accuracy was further partitioned into that uniquely accounted for by variability in physical function, variability in affect, and shared variance between these predictors (see Table 8). Consistent with the latency findings, variability in physical function significantly predicted accuracy in cognitive performance independent of variability in affect/belief status [$F(6,74) =$

[5]It is possible and even common for set correlation to produce error degrees of freedom that include decimals.

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Table 8. Relative contribution of intraindividual variability in physical and affect/belief status as predictors of cognitive performance

	Multivariate R^2 (total)	Multivariate partial R^2 (shared variance)	Multivariate partial R^2 (unique physical)	Multivariate partial R^2 (unique affect)
Latency	.441	.108 (24.5)	.236 (53.5)	.097 (22.0)
Accuracy	.367	.064 (17.4)	.303 (82.6)	.000 (0.0)

Note. Values in parentheses represent percentage of total multivariate R^2 accounted for.

3.63, adjusted multivariate partial $R^2 = .303$]. Also consistent with latency findings, variability in affect/beliefs failed to significantly predict cognitive latency holding variability in physical function constant. Whereas variability in physical function accounted for more than twice as much variance in latency performance relative to variability in affect, the unique influence of physical variability was even more pronounced for cognitive accuracy uniquely accounting for 82.6% of the total variance attributed to variability measures. The remaining 17.4% of the variance was shared between variability in physical function and affect/beliefs with absolutely no variance being uniquely attributed to variability in affect.

Discriminating Neurologically Intact and Dementia Groups

Previous analyses (Hultsch et al., 2000) indicated that the dementia and neurologically intact groups could be reliably differentiated on the basis of both mean performance and variability information. Of particular interest was the finding that intraindividual variability in cognitive performance made an independent contribution to predicting group membership. The present investigation permitted a more detailed assessment of the unique contributions of variability to predicting group membership. Specifically, we examined three different types of intraindividual variability (cognitive, physical, and affect) as a means of differentiating neurologically-intact and dementia groups as well as whether certain types of variability exerted independent predictive influences. Discriminant function analysis was used to estimate the extent to which dementia and nondementia groups (combined) could be differentiated, as well as to evaluate the unique contribution of different types of variability.[6] Separate analyses were run for each measure of cognitive variability (i.e., four separate analyses were run considering the predictive influence of variability in SRT, CRT, word, and story latency separately). In addition to variability in cognitive latency, each discriminant function analysis included measures of physical variability (nondominant finger dexterity and Turn 360) and variability in affect (locus of control and positive affect).

The results for the SRT variability model showed that the combined cognitive, physical, and affect variability information differentiated the dementia from the nondementia groups [$F(5,38) = 7.79$, Wilks's Lambda = .494], correctly classifying 94% of the nondementia participants, 77% of the dementia participants, and 89% overall (see Table 9). Only variability in nondominant finger dexterity uniquely contributed to predicting group membership [$t(38) = 3.60$], although the unique contribution of SRT variability was in the expected direction ($p = .06$). The set of variables for the CRT variability model also combined to differentiate the groups [$F(5,38) = 15.80$, Wilks's Lambda = .325], correctly classifying 97% of the nondementia participants and 85% of the dementia participants (93% overall classification). Both nondominant finger dexterity [$t(38) = 4.84$], and variability in CRT latency [$t(38) = 5.04$], made significant independent contributions to predicting group membership. Groups were also differentiated for the Word variability model [$F(5,38) = 22.04$, Wilks's Lambda = .257], with classification accuracy of 97% for the nondementia participants, 77% for the dementia participants, and 91%

Table 9. Prediction accuracy (%) comparing measures of mean level of cognitive performance and cognitive variability, and variability (cognitive, physical, affect/beliefs) alone

	Dementia (sensitivity)	Nondementia (specificity)	Total
SRT			
Mean and variability	77	91	87
Variability	77	94	89
CRT			
Mean and variability	70	100	91
Variability	85	97	93
Word			
Mean and variability	92	100	98
Variability	77	97	91
Story			
Mean and variability	100	100	100
Variability	85	100	95

Note. Sensitivity and specificity values for mean and variability combined were derived from Hultsch et al. (2000).

[6] An alternative method for this analysis is logistic regression. In the two-group case, discriminant function analysis is exactly comparable to regressing a dichotomous criterion variable on a set of predictors. As our discriminant function software did not permit evaluations of the independent contributions of predictors, we simply regressed the *group* variable on all predictors simultaneously to obtain a test of the unique contribution of each individual predictor.

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overall. Significant independent contributions to predicting group membership were made by nondominant finger dexterity [$t(38) = 2.59$], the Turn 360 task [$t(38) = -2.44$], and variability in word latency [$t(38) = 6.50$], with variability in locus of control approaching the accepted level of significance [$t(38) = 1.85$, $p = .07$]. Finally, the set of variables for the Story variability model combined to differentiate the groups [$F(5,38) = 18.80$, Wilks's Lambda = .288], with classification accuracy of 100% for the nondementia participants, 85% for the dementia participants, and 95% overall classification. Measures of variability making unique contributions to predicting group membership included nondominant finger dexterity [$t(38) = 3.10$], and variability in Story latency [$t(38) = 5.79$]. Overall, the most consistently important variability domain for differentiating group membership was variability in physical performance. Variability in cognitive performance also made consistent unique contributions (only variability in SRT failed to make an independent contribution). Variability in affect had the fewest significant independent effects.

DISCUSSION

We extended the study of intraindividual variability into the domains of physical status and affect/beliefs by investigating their relations with cognitive function in three groups of older adults: healthy elderly, individuals with nonneurological health-related disturbance (arthritis) and people with neurological compromise (dementia). Participants with arthritis were included to help determine whether intraindividual variability is primarily a central nervous system phenomenon or is driven by other health-related phenomena, such as the stress associated with suffering from a chronic disorder. Our findings indicate that inconsistency is not a single or unitary process. Increased variability in physical function appears to reflect central nervous system dysfunction, but marked inconsistency in affect/beliefs appears due to other mechanisms. Individuals diagnosed with mild dementia fluctuated more in their physical performance when compared to neurologically intact individuals. By contrast, the stresses experienced by the participants with arthritis appeared to contribute to their increased fluctuations in affective report, perhaps not a surprising finding given the ups and downs of their pain condition.

The involvement of neurobiological mechanisms in producing inconsistency in physical function is also suggested by the pattern of cross-domain correlations. The analyses indicated consistent patterns of correlations with both (1) level and (2) variability in cognitive function. That is, in agreement with reports of others (Goldstein et al., 1998; Li et al., 2001), we found that individuals who fluctuated more physically (in terms of diastolic blood pressure and nondominant finger-tapping speed) performed worse on measures of memory. People who were more stable physically had better memory. Further, our analyses indicated that intraindividual variability in physical performance was an important independent predictor of level of cognitive performance, accounting uniquely for between 53.5% (latency) and 82.6% (accuracy) of variance in cognitive function. In fact, intraindividual variability in affect/beliefs did not make a significant independent contribution to prediction. Finally, inconsistency in physical performance (blood pressure, gait, nondominant finger-tapping speed) was related to variability in cognitive function (see also Li et al., 2001). However, except for the SRT and the finger dexterity tasks, this cross-domain relation was observed only for the participants with dementia. This is what one would expect to find if there is some general or system-specific neurological compromise contributing to disturbances in both domains.

As indicated above, we observed group differences in the pattern of correlations between physical and cognitive measures of variability. When variability in cognition was assessed with more demanding memory tasks (latency of word or story recognition), positive correlations with fluctuations in physical function (blood pressure, gait, nondominant finger tapping speed) were evident, but typically only for participants with dementia. Interestingly, when processing demands were simpler (SRT), correlations with inconsistency in physical function (nondominant finger tapping speed) emerged regardless of group. This link between inconsistency on simple measures of processing and motor speed may be the behavioral manifestation of an aging brain in our sample of older adults. Declines in elementary cognitive and physical functioning are ubiquitous in aging (Craik & Salthouse, 1992) and connections between these domains have been shown to strengthen with advancing age (Baltes & Lindenberger, 1997; Lindenberger & Baltes, 1994). It must also be acknowledged, however, that the finger tapping task is not a pure measure of physical function but also taps cognitive processes. That is, in addition to fine motor control, there are requirements of attention, speed, and pacing. This might be particularly the case for the nondominant compared to the dominant hand. It would be a mistake, however, to conclude that the cross-domain links that we observed are due only to the cognitive components of the physical tasks. Cross-domain links were also observed for aspects of physical function (blood pressure) with little cognitive demand.

One other issue deserves mention in this context. Common cause accounts of aging (e.g., Baltes & Lindenberger, 1997; Lindenberger & Baltes, 1994) would predict correlations across domains (e.g., between physical and cognitive domains) for the healthy older adults. However, the correlations observed between our measures of physical and cognitive function (both for mean and variability indices) were relatively low in these individuals. In contrast, these correlations were impressively high for the dementia group. Thus, these data offer little evidence of cross-domain linkages among healthy and arthritic individuals, but strong evidence of such a linkage in dementia patients. In this regard, the present study does not support common cause aging accounts. The observation that these cross-domain linkages are present in the dementia cases and less evident in the other groups suggests that there may be specific pathophysiological mechanisms involved in these associations.

Finally, the clinical significance of the measures of intraindividual variability deserves mention. Interestingly, physical variability proved the most consistent predictor of neurological status. The measure of nondominant finger dexterity uniquely identified central nervous system impairment for each of the four discriminant function analyses. That said, both physical and cognitive variability made unique contributions to predicting group membership independent of one another. Only variability associated with the SRT task failed to uniquely discriminate groups. What is perhaps most interesting is the observation that mean level of performance was not included in these models, yet the level of classification remained excellent. Table 9 presents the prediction accuracy for identifying neurological status based on discriminant function analyses of both mean level of cognitive performance and cognitive variability, and variability (cognitive, physical, and affect/beliefs) alone. Note that the measures of variability alone prove to be sensitive behavioral markers of neurological integrity.

In summary, our findings indicate that (1) inconsistency is not a uniform phenomenon. Greater inconsistency in physical performance is observed in groups characterized by central nervous system dysfunction. Fluctuations in affect appear to reflect other sources, such as pain; (2) individual differences in inconsistency in physical function are uniquely predictive of level of cognitive status. In general, increased inconsistency in noncognitive domains is associated with weaker cognitive function; (3) there are cross-domain links between inconsistency in physical functioning and fluctuations in cognitive performance, although the nature of the links depends largely upon the neurological status of the individuals; and (4) measures of cognitive as well as physical variability are important indicators of neurological integrity.

Two key questions arise from our study. First, although the physical–cognitive link was most pronounced among our mixed group of patients with dementia (Alzheimer's and vascular dementia), this study did not address the specificity of the neurological disturbance. There is some evidence that fluctuations in cognition may be more characteristic of some dementing disorders than others. Murtha et al. (2002) gave Stroop and reaction time measures weekly for 5 weeks to individuals with dementia. Increased fluctuations were more likely to occur in patients diagnosed with frontal lobe dementia than with dementia of the Alzheimer type. Walker et al. (2000) recently reported that inconsistency across trials on RT tasks was more prominent in individuals with dementia with Lewy bodies than in persons with vascular dementia or Alzheimer's. They concluded that the marked fluctuations in attention occur continuously in individuals with DLB and reflect a cholinergic deficit. Accordingly, an important question is whether the relations observed in the current study are associated with general nervous system compromise or are associated with certain types of neurological disturbances. A second key issue concerns across-time variation. In this study, we demonstrated cross-domain links; however, we did not consider whether change in one domain covaries with change in another domain over time. An important topic for future research concerns the extent and nature of this interdependency.

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