MOTOR PROGRAMMING AND THE PREDICTION OF EVERYDAY FUNCTIONING

by

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ABSTRACT

The purpose of this study was to examine cognitive reserve, level of cognitive functioning, and motor programming as early markers for detecting declines in everyday functioning. Fifty nondemented, community-dwelling older adults completed a battery of traditional and experimental assessment measures at two time points. The results showed that both overall cognitive functioning and motor programming were useful for identifying individuals at risk for future changes in everyday functioning. The motor programming task did better than overall cognitive functioning in predicting current performances and was the most useful variable for predicting a change in functioning over time.

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BACKGROUND

Everyday functioning is commonly operationalized into two types: (1) basic activities of daily living (ADLs) that include self-care behaviors like bathing, dressing, grooming, feeding, and toileting, and (2) more complex instrumental activities of daily living (IADLs) such as money management, shopping, handling transportation, or medication management (Marcotte, Scott, Kamat, & Heaton, 2010). These activities rely on a number of different factors including cognitive, emotional, physical, and sensory functioning (Barclay, Wright, & Hinkin, 2010). It is well known that everyday functioning becomes compromised as a result of cognitive decline and it has been shown that the moderate stage of dementia (Mini-Mental State Examination [MMSE] score of 16 or below) may be a key transition point at which most IADLs are require significant caregiver support, followed by major losses in basic ADLs (Feldman, Van Baelen, Kavanagh, & Torfs, 2005). In addition to declines in cognition, emotional and behavioral disturbances, such as apathy, disinhibition, or depressed mood can further compromise everyday functioning (Boyle et al., 2003; Fitz & Teri, 1994; Tekin, Fairbanks, O'Connor, Rosenberg, & Cummings, 2001).

Unfortunately, it is also common to observe some degree of functional decline among patients without a diagnosis of dementia but with mild cognitive impairment (Farias et al., 2006; Malloy & McLaughlin, 2010; Tuokko, Morris, & Ebert, 2005; Wadley et al., 2007), surprisingly, even among apparently healthy and nonimpaired community-dwelling older adults (Allaire & Marsiske, 1999; Ball, Ross, & Viamonte, 2010). Among such individuals, functional difficulties do not present as an inability to perform IADLs, but rather functional lapses, errors, or additional support in performing daily tasks. The potential seriousness of such lapses is perhaps best illustrated by the statistics on medication management among older adults. In particular, 87-92% of individuals over age 65 regularly take some form of medication (Gryfe & Gryfe, 1984; Kaufman, Kelly, Rosenberg, Anderson, & Mitchell, 2002), with up to 75% of older adults reportedly having problems with the accurate use of medications, especially with respect to the dosage and timing of administration, or with following special instructions (Barclay et al., 2010; Ostrum, Hammarlund, Christensen, Plein, & Kethley, 1985). Because, apparently, healthy and independent older adults are also prone to making such mistakes (Barclay et al., 2010; Burton, Strauss, Hultsch, & Hunter, 2006; Ostrum et al., 1985) physicians may underestimate or fail to recognize functional disabilities in their patients once a diagnosis of dementia or MCI is ruled out (Calkins et al., 1991). Such lapses among noncognitively impaired persons are associated with considerable comorbidity, ranging from suboptimal management of medical or psychiatric conditions (Col, Fanale, & Kronholm, 1990) to complications associated with overdose (Greenberg, 1984), or even death (Osterberg & Blaschke, 2005).

The etiology of functional lapses in ADL/IADLs is likely multidetermined. On the one hand, functional lapses can be exacerbated by issues that are unrelated to cognition. For example, investigators have found that IADL disabilities among older adults are associated with psychopathology, including depression or personality disorders, (Abrams, Alexopoulos, Spielman, Klausner, & Kakuma, 2001; Ormel, Rijsdijk, Sullivan, van Sonderen, & Kempen, 2002), chronic medical conditions (Boult, Kane, Louis, Boult, & McCaffrey, 1994), low frequency of social contacts (Seeman et al., 1995), alcohol use (LaCroix, Guralnik, Berkman, Wallace, & Satterfield, 1993), or poor self-perceived health (Idler & Kasl, 1995). Similarly, physical limitations due to disease comorbidity, changes in body mass index, low level of physical activity, and sensory impairment can limit everyday functional abilities (Seeman et al., 1994; Stuck et al., 1999; Wadley, Okonkwo, Crowe, & Ross-Meadows, 2008).

On the other hand, healthy older adults as a group are known to exhibit age-related cognitive changes that include declines in mental processing speed (Baudouin, Vanneste, & Isingrini, 2004; Salthouse, 1996), psychomotor speed (Ferris, Crook, Sathananthan, & Gershon, 1976), memory (Blanchard-Fields & Hess, 1996; Craik & Salthouse, 1992), and executive abilities (Krampe, 2002). From among these cognitive abilities, executive functioning (EF) has emerged as the most consistent predictor of everyday abilities (Bell-McGinty, Podell, Franzen, Baird, & Williams, 2002; Bryan & Luszcz, 2000; Chaytor & Schmitter-Edgecombe, 2003; Grigsby, Kaye, Baxter, Shetterly, & Hamman, 1998; Grigsby, Kaye, Kowalsky, & Kramer, 2002; McCue, Rogers, & Goldstein, 1990; Razani et al., 2007; Royall, 2000; Suchy, Blint, & Osmon, 1997). EF has been found to be most strongly associated with IADLs in patients with depression (Kiosses, Klimstra, Murphy, & Alexopoulos, 2001), bipolar disorder (Gildengers et al., 2007), HIV infection (Heaton et al., 2004), cardiovascular disease (Jefferson, Paul, Ozonoff, & Cohen, 2006), vascular dementia (Boyle, Paul, Moser, & Cohen, 2004), and Alzheimer’s disease (Farias, Harrell, Neumann, & Houtz, 2003). Importantly, EF is also associated with functional changes even among nondemented community-dwelling older individuals, with EF measures accounting for more variance in functional status than other cognitive abilities (e.g., memory, language, and spatial skills) or demographic characteristics (e.g., age, education, and health status) (Cahn-Weiner, Boyle, & Malloy, 2002). However, little is known about how subtle, incipient changes in cognition among apparently independent older adults gradually begin to affect changes in functional status, or at which point individuals with mild cognitive decline become at risk for future lapses in functionality.

Predicting Future Functional Change

There is some precedent for predicting future functional trajectories among older adults. Prior research has utilized (1) indicators of cognitive reserve (i.e., education and crystallized intelligence) as protective factors against future declines, (2) marginal level of cognitive performance to predict conversion to dementia, and (3) motor functioning as a predictor of declining functional independence. These will be briefly reviewed below.

Cognitive Reserve

Cognitive reserve is thought to represent a dynamic process in development and in aging that has critical implications for cognitive functioning in later life (Mortimer, Snowdon, & Markesbery, 2007; Richards, Sacker, & Deary, 2007). It is believed that individuals with greater cognitive reserve may be more successful in coping with certain kinds of brain damage as the result of the cognitive processing approaches they have developed earlier in life, or as the result of compensatory mechanisms that are activated in response to brain damage (Stern, 2007). In fact, there is growing evidence that suggests high premorbid intellectual ability, as reflected in attained crystallized intelligence and educational achievement, may help delay or diminish the clinical expression of dementia despite the presence of neuropathological changes (Bieliauskas & Antonucci, 2007; Richards et al., 2007). Cognitive reserve is also associated with better awareness of functional declines, thereby perhaps facilitating implementation of compensatory strategies (Suchy et al., under review). Thus, if cognitive reserve protects one from cognitive decline and facilitates compensation, it is also possible that higher cognitive reserve would protect one from functional decline.

Level of Cognitive Functioning

The notion that a decreased level of cognitive functioning, most notably mild cognitive impairment (MCI), can be used for the prediction of future declines originated from efforts to better characterize the transitional phase between normal aging and dementia (Petersen, 2005, 2007; Ritchie & Touchon, 2000). Although the construct of MCI was originally conceptualized as a mild impairment of memory in the absence of other cognitive problems (Petersen et al., 1999), more recent conceptualizations have included mild difficulties in other cognitive domains (Lopez et al., 2006; Petersen et al., 2001). Annual rates of conversion from MCI to dementia vary widely across studies from 2-31% with a meta-analysis of research indicating a mean conversion rate of 10.24% (Bruscoli & Lovestone, 2004). MCI has been linked to a faster rate of decline in specific cognitive abilities (Amieva et al., 2004; Levey, Lah, Goldstein, Steenland, & Bliwise, 2006), an increased incidence of Alzheimer's disease or other dementias (Tschanz et al., 2006), and an increased risk of death (Bennett et al., 2002). Although

MCI is specifically distinguished from dementia by the absence of deficits in everyday functioning, mild cognitive difficulties may represent a predictor of future declines in functionality and hence a conversion to dementia.

Motor Programming

Motor performances appear to become more effortful with age (Heuninckx, Wenderoth, Debaere, Peeters, & Swinnen, 2005; Heuninckx, Wenderoth, & Swinnen, 2008; Trewartha, Endo, Li, & Penhune, 2009), and older individuals demonstrate longer reaction times, longer motor planning latencies, slower movement speeds, and less fluid movements than younger adults (Christe, Burkhard, Pegna, Mayer, & Hauert, 2007; Sterr & Dean, 2008; Yan, 2000; Yan, Thomas, Stelmach, & Thomas, 2000). Such changes are thought to be associated with age-related and perhaps subclinical decreases in executive and attentional control (Sterr & Dean, 2008; Trewartha et al., 2009), and motor programming has been used as a proxy for assessment of executive functioning among older adults (Grigsby, Kaye, & Robbins, 1992; Suchy & Kraybill, 2007).

Although declines in motor abilities can vary considerably across individuals, they appear to be accelerated in individuals with neurodegenerative disorders such as Alzheimer's disease (Carrasco, Guillem, & Redolat, 2000; Ott, Ellias, & Lannon, 1995; Yan & Dick, 2006). Thus, changes in motor performances have been shown to help differentiate between normal aging, MCI, and dementia (Belanger et al., 2005; Hall & Harvey, 2008; Yan & Dick, 2006). Additionally, gross motor skills have been shown to predict future disability (Guralnik, Ferrucci, Simonsick, Salive, & Wallace, 1995; Guralnik et al., 1994; Marquis et al., 2002) and more complex motor programming has been shown to predict apathy and impulsivity (Kaye, Grigsby, Robbins, & Korzun, 1990), problems in functional independence (Grigsby et al., 1998; Grigsby, Kaye, Eilertsen, & Kramer, 2000; Grigsby, Kaye, Kowalsky et al., 2002), as well as institutionalization of medical inpatients 3 months after an initial assessment (Suchy et al., 1997).

The purpose of the present study was to examine whether the three constructs reviewed above (i.e., cognitive reserve, level of cognitive functioning, or motor functioning) could serve as early markers for a decline in functionality. To that end, we assessed a sample of 50 community-dwelling elderly participants at two time points using a battery of traditional and experimental assessment measures. Given that we were interested in identifying *subtle* deficits in everyday functioning that are often difficult to detect with the self-report measures commonly used in clinical settings, we used a behavioral assessment of functionality at both time points.

METHODS

Participants

Seventy-five older adult participants were originally recruited through an informational booth at the Salt Lake County Senior Expo. Since we were specifically interested in evaluating relatively high-functioning individuals, only participants whose cognitive screening was in the normal range (i.e., Mattis Dementia Rating Scale $\geq$ 123) (Mattis, 1988) were included in the study. From this sample, 50 participants agreed to return for follow-up testing that took place approximately 1.4 years after the initial evaluation. Attrition was due to participants declining follow-up testing for unspecified reasons (n=11), being unreachable (e.g., disconnected phone number) (n=8), having other personal obligations such as care-giving responsibilities (n=3), feeling that it was too far to travel (n=2), and reported functional changes that made it too difficult to participate (e.g., onset of dementia) (n=1). Participants who completed follow-up testing were not significantly different from those who did not return in terms of age, education, gender, depression, or self-reported IADLS. Returners did, however, have significantly higher scores on the Mattis Dementia Rating Scale [t=-4.2(73), p<.001] (Table 1). Some of the returning participants reported chronic health problems that they characterized as mild, including hypertension (n=19), sleep apnea (n=5), stroke (n=3), seizure disorder (n=2), heart disease (n=1), and chronic obstructive pulmonary disease (n=1). Ninety percent of

Table 1

Participant Characteristics

		Nonreturners (*n*= 25) 40% Male	Returners (*n* = 50) 36% Male	*p v*alue
Age [a]	Mean	70.96	69.46	
	SD	7.41	6.41	.37
	Range	61-87	58-87	
Education	Mean	14.52	14.70	
	SD	13.00	2.24	.77
	Range	12-22	10-18	
Initial DRS [b]	Mean	135.28	139.44	
	SD	5.91	3.32	<.001
	Range	123-144	130-144	
GDS [c]	Mean	6.16	4.52	
	SD	4.0	4.16	.20
	Range	0-26	0-23	
Self Report IADLS [d]	Mean	23.60	23.48	
	SD	0.87	0.81	.56
	Range	20-24	21-24	
Follow-up time [e]	Mean	-	1.41	
	SD	-	0.53	-
	Range	-	0.64-2.67	
Follow-up DRS [b]	Mean	-	138.12	
	SD	-	5.03	-
	Range	-	123-144	

Note. [a] Age at initial assessment. [b] Mattis Dementia Rating Scale. [c] Geriatric Depression Scale. [d] Instrumental Activities of Daily Living Total Score. [e] Interval time between testing sessions in years.

participants characterized their health as good to excellent. Ten percent characterized their health as fair. See Table 1 for a summary of participant characteristics.

Procedure

Participants were screened over the telephone at both the initial and follow-up time points regarding exclusion criteria (i.e., color blindness, uncorrected vision or hearing problems, difficulty using the right hand, left-handedness, or a diagnosis of dementia). On the day of testing, participants underwent informed consent procedures, followed by completion of a battery of neuropsychological tests and questionnaires (listed below). Both testing sessions lasted approximately 2 to 3 hours, with breaks provided as needed. Participants were reimbursed at the rate of $30 per initial session and $20 per follow-up session. Participants were also provided brief feedback regarding their cognitive and depression screening.

Measures

Global Cognitive Functioning

Mattis Dementia Rating Scale (DRS-2) (Mattis, 1988)

The DRS-2 is a screening measure used in the assessment of general cognitive status and includes domains of attention, initiation, abstraction, visual-constructional abilities, and verbal as well as nonverbal memory; the DRS-2 has a reliability of .97 (Shay et al., 1991). Consistent with normative studies (Mattis, 1988), a DRS-2 cutoff score of 123 was used for inclusion in the study so as to exclude participants who might exhibit early signs of dementia. Previous studies have suggested a relationship between the DRS-2 and concurrent everyday functioning (Nadler, Richardson, Malloy, Marran, & Hosteller Brinson, 1993; Vitaliano et al., 1984).

Cognitive Reserve

Wechsler Adult Intelligence Scale, 3rd Edition Information Subtest (WAIS-III Info) (Wechsler, 1997b)

The WAIS-III Information subtest is believed to be a measure of crystallized intelligence (Gignac, 2006), which has been shown to be less vulnerable to the effects of aging than fluid intelligence (Ryan, Sattler, & Lopez, 2000). Crystallized intelligence is a construct thought to reflect acquired experience and knowledge (Milgram, Siwak-Tapp, Araujo, & Head, 2006) and is influenced by education (Kramer, Bherer, Colcombe, Dong, & Greenough, 2004). Given that early life experiences and measures of crystallized intelligence have been found to have neuroprotective effects (Milgram et al., 2006), the WAIS-III Info subtest was used to provide an estimate of cognitive reserve. WAIS-III Info has been used by other researchers as a measure of cognitive reserve (Rubin et al., 1998; Smith et al., 2007) and has a reliability of .91 (Wechsler, 1997a).

Years of education

Cognitive reserve has traditionally been assessed using both crystallized intelligence and educational achievement, with substantial research arguing for the inclusion of years of education as a component measure of cognitive reserve (Richards et al., 2007; Stern et al., 1994; White et al., 1994). Therefore, years of completed education, as reported by participants, was used as a second index of cognitive reserve.

Motor Functioning

Push Turn Tap-tap Task (Suchy, Derbidge, & Cope, 2005)

The Push Turn Tap-tap (PTT) task is an electronic motor programming (MP) task in which participants are required to learn four different sequences of three distinct hand movements using a specialized response console (Suchy et al., 2005; Suchy & Kraybill, 2007). The three hand movements are: (a) “Push”-- pushing the joystick forward, (b) “Turn”-- turning the joystick clockwise, and (c) “Tap-tap”-- double-tapping on the white dome. Participants start with a block in which they learn a two-movement sequence, followed by blocks of three-, four-, and five-movement sequences. Each block begins with a presentation of the sequence on the computer screen; after three correct sequences, the screen presentation disappears and participants are expected to perform the sequences from memory. Mistakes are indicated by an audible ding followed by a presentation of the correct sequence on the screen. Participants are asked to correct their mistake and then to proceed with the remainder of the sequence. Each block continues until five correct sequences are completed, but is terminated if five correct sequences are not achieved in 10 trials.

The PTT task generates a comprehensive index of motor programming skills, with a Cronbach's alpha reliability in the present sample of .812. This index is a composite of several key aspects of MP, and was calculated by using a factor analysis of the three MP variables described below (M-PLN, M-LRN, M-CNT):

Motor Planning (M-PLN) refers to the covert preparation that precedes an intended movement (Banich, 2004). Longer movement sequences have been shown to require longer planning latencies (Wright, Black, Immink, Brueckner, & Magnuson,

2004) and imaging studies suggest that movement preparation may be neuro-anatomically dissociable from the action itself (Hanakawa, Dimyan, & Hallett, 2008; Hoshi & Tanji, 2004). The PTT task assesses M-PLN by measuring the median amount of time (in milliseconds) that elapses between completion of one sequence and initiation of a new *correct* sequence. M-PLN time has been shown to increase with age (Christe et al., 2007; Sterr & Dean, 2008; Suchy & Kraybill, 2007).

Motor-Learning (M-LRN) is the process by which a new task is successfully mastered and is reflected in the total number of errors made on the task (Suchy & Kraybill, 2007). M-LRN abilities have been shown to decrease with age (Boyd, Vidoni, & Siengsukon, 2008; Suchy & Kraybill, 2007).

Motor Control (M-CNT) is the ability to correctly execute discrete aspects of a movement and was assessed by examining the smoothness and accuracy of the tap-tap movement. Specifically, the M-CNT variable is a factor score comprised of (a) perseverative errors (e.g., triple or quadruple taps) during the tap-tap movement and (b) the latency between the two taps. Assessment of M-CNT has been found to help identify early stages of dementia, independent of the effects of age, gender, and education (Kluger, Gianutsos, Golomb, Ferris, & Reisberg, 1997) and may also help improve identification of at risk nondemented elderly individuals A matrix of correlations among the measures can be found in Table 2.

Everyday Functioning

Timed Instrumental Activities of Daily Living (TIADL) (Owsley, Sloane, McGwin, & Ball, 2002)

Table 2

Correlation Matrix

	Initial DRS-2[e]	WAIS-III Info [b]	Education	MP Comp [c]	TIADL Speed [d]	TIADL Errors [e]	TIADL Comp [f]
Initial DRS-2[a]	1.00						
WAIS-III Info [b]	.232	1.00					
Education	.262	.496**	1.00				
MP Comp. [c]	-.576**	-.356*	-.398	1.00			
TIADL Speed [d]	-.076	.094	-.185	.383**	1.00		
TIADL Errors [e]	-.336*	.084	.005	.352*	.249	1.00	
TIADL Comp [f]	-.186	-.051	-.300*	-.402**	.559**	.226	1.00

Note. n=50. * $p < .05$. ** $p <.01$. [a] Mattis Dementia Rating Scale, total, [b] Wechsler Adult Intelligence Scale – III Information subtest, [c] Motor programming composite of the Push-Turn-Taptap task. Lower values reflect better performances, [d] Timed Instrumental Activities of Daily Living, mean speed. Lower values reflect better performances, [e] Timed Instrumental Activities of Daily Living, errors. Lower values reflect better performances. [f] Timed Instrumental Activities of Daily Living, composite. Lower values reflect better performances.

The TIADL task is a measure of daily living competency that assesses speed and accuracy of common abilities including finding a telephone number, making change, reading the ingredients on a can of food, finding food items on a shelf, and reading instructions on a medicine container (Owsley et al., 2002). The TIADL takes about 5 minutes to administer and has a test-retest reliability of .85 (Owsley et al., 2002). Consistent with the methodology used by Owsley et al. (2002), z-scores for the latencies (measured in milliseconds) for each of the TIADL tasks were computed and the mean of z scores was used in the analyses for TIADL speed. A composite score of both components of the TIADL task (speed and errors) was calculated by using a factor analysis of the mean TIADL speed and total TIADL errors.

RESULTS

Correlates of Current and Future Functioning

We first examined zero-order correlations among the independent and dependent variables. As can be seen in Table 3, age was correlated with the follow-up TIADL composite, and education was correlated with the initial TIADL composite. Initial MP performance was correlated with time, errors, and the TIADL composite at both time points. Initial DRS-2 performance was also correlated with TIADL errors at follow-up. See Table 3.

Because the time interval between the two assessments varied across participants, we next examined the relationship between predictor variables and follow-up TIADL performances after statistically controlling for the time between assessments. In a similar fashion, we also examined the relationship between initial and follow-up assessments. The results remained virtually unchanged from the zero-order correlations reported in Table 2, with the initial DRS-2 again predicting TIADL errors at follow-up, and the MP composite again predicting speed, errors, and the TIADL composite score at follow-up. Additionally, participants' speed of TIADL performance at baseline was found to predict speed, errors, and the TIADL composite at the time of follow-up. The initial TIADL composite was correlated with TIADL follow-up speed and the follow-up TIADL composite. See Table 4.

Table 3

Bivariate Pearson Product Correlations

	Initial performances			Follow-up performances		
	TIADL speed [a]	TIADL errors [b]	TIADL composite [c]	TIADL speed [a]	TIADL errors [b]	TIADL composite [c]
Age	.207	.012	.141	.197	.265	.292*
Education	-.223	-.243	-.300*	-.185	.005	-.113
Gender [d]	.027	.108	.087	-.119	.029	-.057
Initial DRS-total [e]	-.078	-.210	-.186	-.076	-.336*	-.261
WAIS-III Info. [f]	.074	-.154	-.051	.094	.084	.112
MP-Composite [g]	.283*	.341*	.402**	.383**	.352*	.465**

Note. n=50. * $p < .05$. ** $p < .01$. [a] Timed Instrumental Activities of Daily Living, mean speed. Lower values reflect better performances. [b] Timed Instrumental Activities of Daily Living, errors. Lower values reflect better performances. [c] Timed Instrumental Activities of Daily Living, composite. Lower values reflect better performances. [d] Gender coded as male = 1. [e] Mattis Dementia Rating Scale, total. Higher values reflect better performances. [f] Wechsler Adult Intelligence Scale – III Information subtest. Higher values reflect better performances. [g] Motor programming composite of the Push-Turn-Taptap task. Lower values reflect better performances.

Table 4

Partial Correlations Controlling for the Time Between Evaluations

	Follow-up TIADL speed [a]	Follow-up TIADL errors [b]	Follow-up TIADL composite [c]
Initial TIADL speed [a]	.693**	.282*	.618**
Initial TIADL errors [b]	.201	.091	.185
Initial TIADL composite [c]	.577**	.241	.518**
WAIS-III Info [d]	.091	.080	.109
Education	-.190	-.001	-.121
DRS total [e]	-.070	-.331*	-.254
MP composite [f]	.381*	.349*	.462*

Note. $n = 50$. * $p < .05$. ** $p < .001$. [a] Timed Instrumental Activities of Daily Living, mean speed. Lower values reflect better performances. [b] Timed Instrumental Activities of Daily Living, errors. Lower values reflect better performances. [c] Timed Instrumental Activities of Daily Living, composite. Lower values reflect better performances. [d] Wechsler Adult Intelligence Scale – III Information subtest. Higher values reflect better performances. [e] Mattis Dementia Rating Scale, total. Higher values reflect better performances. [f] Motor programming composite of the Push-Turn-Taptap task. Lower values reflect better performances.

Predictors of Change and Decline in Functioning

In order to better understand which variables contributed to *changes over time* in everyday functioning performances we conducted a series of hierarchical regression analyses, using the TIADL composite at follow-up as the criterion variable. At Step 1, we entered the interval between assessments. At Step 2, we entered the initial TIADL composite so as to account for baseline performance. In three separate analyses, Step 3 tested the degree to which our predictor variables (i.e., cognitive reserve, level of cognitive functioning, and motor programming) accounted for variance above and beyond the interval time and the initial TIADL performances. Specifically, to examine the contribution of cognitive reserve, WAIS-III Information and years of education were entered at Step 3. To examine the contribution of cognitive functioning, the initial DRS-2 total raw scores were entered at Step 3. To examine the contribution of motor programming, the MP composite was entered at Step 3. See Table 5 for a summary of these models.

As can be seen in the table, initial TIADL performances predicted follow-up performances. The cognitive reserve variables were not shown to be useful predictors of TIADL performance. Even though the DRS-2 was correlated with errors at the time of follow-up, it was not useful in predicting *change* (i.e., performance above and beyond the interval time and initial TIADL performances). In contrast, the MP composite emerged as a significant predictor of change in TIADL performances.

Table 5

Summary of Hierarchical Regression Models for TIADL Composite

Criterion variable	Step	Predictors	Adjusted R^2	$R^2\Delta$	$F\Delta$	*p* value
Follow-up TIADL composite [a]	1	Interval time [b]	-.015	.005	.264	.610
	2	Initial TIADL composite [a]	.241	.267	17.22	<.001
	3	WAIS-III Info [c], Education	.228	.019	.592	.558
	3	Initial DRS total [d]	.248	.022	1.41	.242
	3	MP composite [e]	.301	.071	5.00	.030

Note. *n*=50. Step 3 reflects three separate analyses examining contributions above steps 1 and 2. [a] Timed Instrumental Activities of Daily Living, composite. [b] Interval time between testing sessions. [c] Wechsler Adult Intelligence Scale-III, Information subtest. [d] Mattis Dementia Rating Scale, total. [e] Motor programming composite.

Identification of Decliners

In order to further examine our predictor variables (e.g., WAIS-III Info, education, DRS-2, and MP) in terms of their utility in classifying individuals who declined the most, we conducted a Receiver Operating Characteristic (ROC) curve analysis, using the follow-up TIADL composite residuals (after accounting for the baseline TIADL composite, reflecting the change in functionality from the baseline assessment) as the criterion variable. Participants were split into those who demonstrated the largest magnitude of decline (i.e., 1 standard deviation above the sample mean, *n*=5) versus the rest of the sample (*n*=45). The results showed that the MP composite reliably classified participants into decliners and nondecliners (*AUC*=.889, *p*=.005) with a 100% sensitivity and an 80% specificity. While the DRS-2 also reliably classified participants (*AUC*=.804, *p*=.027), it exhibited much lower specificity (i.e., a 100% sensitivity was accompanied by only a 46% specificity, and an 80% sensitivity was accompanied by a 73% specificity). Interestingly, the small group of decliners exhibited mean baseline DRS-2 scores that were virtually identical to those of nonreturners (i.e., *M*=135.8, *SD*=3.90). See Table 1.

DISCUSSION

The purpose of this study was to examine whether a) cognitive reserve, b) level of cognitive functioning, or c) motor programming (MP) could serve as early markers for detecting future declines in everyday functioning in a sample of nondemented, community-dwelling older adults. Predicting future declines in everyday functioning is an important focus of research given that lapses in functionality may be indicative of disease onset (Nygard, 2003) and may have serious consequences for one's health and safety (Marcotte et al., 2010). The current study sought to evaluate the three previously mentioned hypotheses and assess functional changes over time using a longitudinal study design.

The results show that initial performances on the Timed Instrumental Activities of Daily Living (TIADL) test were a good predictor of future TIADL performances, which is consistent with the literature regarding the prediction of neuropsychological change (Attix et al., 2009; Backman, Hill, Herlitz, Fratiglioni, & Winblad, 1994; Duff et al., 2004, 2005, 2008; Temkin, Heaton, Grant, & Dikmen, 1999). The results also supported our hypothesis regarding MP as a useful predictor of declines in everyday functioning. Unlike the other variables, MP was associated with both *current* and *future* functioning, as well as a *change* in everyday functioning over time. In contrast, baseline level of cognition (as assessed via the DRS-2) only predicted future accuracy of TIALD performance, but not future speed or future change, and cognitive reserve was unrelated to functionality. Lastly, although both MP and DRS-2 reliably identified participants who exhibited a functional decline of 1 standard deviation or more, only MP had sensitivity and specificity rates that were high enough to be clinically useful. More detailed discussion of these findings follows.

Motor Programming and Daily Functioning

MP may be particularly relevant to *current* functioning (both speed and errors), given that many everyday tasks specifically require efficiency and accuracy of coordinated behavioral output. Successful everyday functioning likely requires components of MP (e.g., learning, planning, and control) in order to facilitate the manipulation of objects in the environment and organize actions. Similarly, the link between MP and everyday functioning may be related to its association with executive functioning (EF) (Belanger et al., 2005; Suchy & Kraybill, 2007), which in turn is widely believed to be an important determinant of functional status (Cahn-Weiner, Boyle, & Malloy, 2002; Marson & Hebert, 2006; Mitchell & Miller, 2008b), since various components of behavioral control, such as initiation, inhibition, set maintenance, set switching, working memory, attention, problem-solving, self-monitoring, etc., are relevant to everyday functioning (Chaytor & Schmitter-Edgecombe, 2003; Long, 1996).

It is also important to consider why MP was associated with *future* functioning and the prediction of *change*. Cross sectional studies have suggested that aging is associated with a shift along a continuum from automatic to more controlled processing of movement, which requires increased cognitive monitoring, added attentional demands, increased reliance on EF, more pronounced processing of sensory information, and additional need for intersensory integration (Heuninckx et al., 2005; Sterr & Dean, 2008; Trewartha, Endo, Li, & Penhune, 2009). These age-related changes may have direct implications for everyday functioning as tasks that require coordinated movements become more controlled, effortful, and error prone, thus requiring greater reliance on available cognitive resources. Consequently, an assessment of MP may provide valuable information about where someone is along that continuum and in turn help anticipate a susceptibility to future functional declines.

MP tasks have in fact been shown to help predict functional changes among a number of specific patient populations, including patients with various forms of dementia (Boyle, Cohen, Paul, Moser, & Gordon, 2002; Kluger, Gianutsos, Golomb, Ferris, & Reisberg, 1997), inpatient rehabilitation patients (Suchy et al., 1997), and among individuals with depression (Heuninckx, Wenderoth, Debaere, Peeters, & Swinnen, 2005; Kiosses et al., 2001). MP has also been shown to predict future pathology among children (Denckla, 2005; Wolff, Gunnoe, & Cohen, 1985). However, there have been few studies examining MP in healthy older adults (Belanger et al., 2005; Grigsby, Kaye, & Robbins, 1995; Grigsby, Kaye, Shetterly et al., 2002) and no studies examining MP as a predictor of future functional changes among healthy community dwelling individuals. Thus, the results of this study extend previous research conducted with patient populations and suggest that MP tasks may be useful for predicting functional changes or identifying individuals at risk for functional decline even among nondemented, community-dwelling older adults. In fact, MP showed high, clinically useful, sensitivity (100%) and specificity (80%) rates. Thus, pending replication of the present findings, MP may prove to be a useful screening instrument in clinical settings.

Cognition and Daily Functioning

Similar to MP, initial cognitive functioning (as measured by the DRS-2) was associated with future everyday functioning errors. Although this finding is also consistent with the literature that suggests that global cognitive impairments are generally associated with worse performances on everyday functioning measures (Carey et al., 2004; Marcotte et al., 2010), the relationship with concurrent functionality was less strong and did not reach statistical significance, perhaps due to a somewhat constricted range of scores on both the DRS-2 and the TIADL at baseline in this relatively high functioning sample. However, individuals with MCI have been shown to experience functional declines associated with incipient dementia (Albert et al., 1999; Farias et al., 2006; Wadley et al., 2007); thus, the subtle declines in functionality among those individuals who had somewhat lower DRS-2 scores at baseline may have been sufficient to increase the relationship between the DRS-2 and functionality. This same issue may explain why the DRS-2 classified individuals who declined, but was *not* associated with declines when examined in a linear regression. In other words, the association between DRS-2 and functionality only held for those individuals who were at the tail of an otherwise relatively constricted range of performances. Importantly, even for those individuals, the DRS-2 was not as successful as MP at identifying decliners, exhibiting sensitivity and specificity of questionable clinical utility.

Lower DRS-2 scores may be more successful at predicting future declines in functionality than the present study demonstrates given that those individuals who did not return for the second assessment had somewhat lower DRS-2 scores at baseline (see Table 1) and their mean DRS-2 scores were comparable to those of decliners. In other words, it is possible that at least some participants refused to return for second testing due to declines in functionality.

Cognitive Reserve and Daily Functioning

Despite growing support for the clinical utility of the concept of cognitive reserve (Stern, 2007), our hypothesis regarding its predictive utility was not supported, as indices of cognitive reserve were not correlated with future everyday functioning performances or a change in functionality. These negative findings may be related to the sample itself. In particular, participants were relatively highly educated and only demonstrating/reporting mild everyday functioning problems. Participants in this sample presumably had more uniformly high levels of cognitive reserve than the general population and perhaps very few participants had reached that threshold of reserve that would make functional problems become evident. An alternative explanation is that there may still be better ways to operationalize cognitive reserve. For example, synaptic density or neural network integrity may be a better way of characterizing a reserve capacity and functional brain imaging or event-related potential data may uncover compensatory brain activity. While these may be interesting directions for future research, our results suggest that at least for relatively high functioning individuals, it is still difficult to detect one's risk for future functional lapses based on variables that are traditionally believed to assess cognitive reserve.

In summary, the current study found that both overall cognitive functioning as measured by the DRS-2 and MP were useful for identifying individuals at risk for future changes in everyday functioning, although MP exhibited higher sensitivity and specificity. The MP task also did better than the DRS-2 in predicting *current* everyday functioning performances and was the most useful variable for predicting a *change* in functioning over time. It may be important to consider how MP tasks could be incorporated into clinical evaluations, given that there are a number of specific advantages to using such measures. For example, MP tasks may provide a more direct assessment of the abilities that are required for everyday functioning and may alleviate some of the confounds that are associated with traditional EF measures (Suchy & Kraybill, 2007). MP tasks also provide the benefit of being relatively efficient to administer, and tasks that are more time-efficient have important practical and clinical advantages.

Limitations

The primary limitation of the present study is its relatively modest sample size. While this was less of an issue when the data were analyzed as continuous, it was somewhat problematic when the sample was divided into decliners and nondecliners and nonparametric analyses (ROC) were conducted. Therefore, at present, the ROC analyses should be viewed as a supplementary illustration of the potential clinical utility of the MP task, and a replication with a larger sample of decliners is needed. Additionally, replication with a larger sample that includes a wider range of functional abilities would provide additional information about the potentially predictive utility of the DRS-2, which may have suffered from a constrained range.

Although the variability in when participants returned for follow-up testing may be viewed as a weakness, we controlled for the interval time in our analyses and it did not appear to account for a significant amount of variance in future performances. Replicating this study with a longer period of time between testing sessions would help clarify how MP does at predicting more permanent functional changes.

Like most longitudinal studies, this study suffered some attrition of participants over time. In the present study, it appears that this attrition may have led to an underestimate of the clinical utility of the DRS-2 as a predictor of future decline, given that the participants who completed the study had higher DRS-2 scores than those who did not. Given that lower DRS-2 scores identified individuals who exhibited considerable declines in functioning, it is possible that the participants who did not return also had declines in functioning, which may have precluded them from returning to a second assessment session.

Finally, the testing environment (which is inherently novel) may introduce confounding factors such as test anxiety that can temporarily affect performances in such a unique setting. The novelty of computerized tasks may also cause some apprehension, particularly for older adults. Furthermore, while the brevity of the MP task is beneficial, it may not provide information about stamina and response to fatigue which may be especially important for maintaining everyday functioning abilities.

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