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Cognitive Predictors of Everyday Functioning in Older Adults: Results From the ACTIVE Cognitive Intervention Trial

Alden L. Gross,[1] George W. Rebok,[1] Frederick W. Unverzagt,[2] Sherry L. Willis,[3] and Jason Brandt[1,4]

[1]Department of Mental Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland.
[2]Department of Psychiatry, Indiana University School of Medicine, Indianapolis.
[3]Department of Psychiatry and Behavioral Sciences, University of Washington, Seattle.
[4]Department of Psychiatry and Behavioral Sciences, Johns Hopkins University School of Medicine, Baltimore, Maryland.

Objective. The present study sought to predict changes in everyday functioning using cognitive tests.

Methods. Data from the Advanced Cognitive Training for Independent and Vital Elderly trial were used to examine the extent to which competence in different cognitive domains—memory, inductive reasoning, processing speed, and global mental status—predicts prospectively measured everyday functioning among older adults. Coefficients of determination for baseline levels and trajectories of everyday functioning were estimated using parallel process latent growth models.

Results. Each cognitive domain independently predicts a significant proportion of the variance in baseline and trajectory change of everyday functioning, with inductive reasoning explaining the most variance (R^2 = .175) in baseline functioning and memory explaining the most variance (R^2 = .057) in changes in everyday functioning.

Discussion. Inductive reasoning is an important determinant of current everyday functioning in community-dwelling older adults, suggesting that successful performance in daily tasks is critically dependent on executive cognitive function. On the other hand, baseline memory function is more important in determining change over time in everyday functioning, suggesting that some participants with low baseline memory function may reflect a subgroup with incipient progressive neurologic disease.

Key Words: Cognition—Cognitive training—Everyday functioning—Structural equation modeling.

THE knowledge, capacities, and skills needed to autonomously care for oneself in the community environment, referred to as everyday functioning, decline with age (Katz, Ford, Moskowitz, Jackson, & Jaffe, 1963; Loewenstein & Mogosky, 1999; Willis, 1996). Impaired functioning is predictive of adverse health care outcomes, such as hospitalizations and nursing home admissions (Fillenbaum, 1985; Fogel, Hyman, Rock, & Wolk-Klein, 2000). Everyday functioning is also important to neuropsychologists and cognitive researchers because functional decline is a precursor to, and indeed a criterion for, dementia (American Psychiatric Association, 2000), and clinicians are often asked to predict a patients' ability to function in the community.

Assessment of everyday functioning in population-based research varies widely based on the measurement tools used and theoretical assumptions made (Richardson, Nadler, & Malloy, 1995; Royall et al., 2007). Instrumental activities of daily living (IADLs) are commonly distinguished from more basic physical self-care activities of daily living (ADLs) because IADLs entail more cognitively complex tasks, such as cooking, taking prescribed medications, and managing finances (Katz et al., 1963; Lawton & Brody, 1969; Willis, 1996). IADLs decline before ADLs and are more strongly associated with independent everyday functioning in the community (Njegovan, Man-Son-Hing, Mitchell, & Molnar, 2001; Willis, 1996). Functional IADL ability is often assessed through self-reports or proxy ratings of an individual's ability to perform activities (Dorevitch et al., 1992; Harper, 2000; Jette et al., 2002; Lawton & Brody, 1969) but can also be assessed using objective performance measures of physical and cognitive tasks important to everyday functioning (e.g., Nadler, Richardson, & Malloy, 1993; Willis & Marsiske, 1993). In addition to measurement considerations, particular everyday abilities are related to important predictors in different ways; this underscores the importance of defining the scope of everyday functioning (Hertzog, Kramer, Wilson, & Lindenberger, 2008). For example, everyday functioning might refer to broad global abilities or to more specific abilities, such as everyday problem solving (Allaire & Marsiske, 1999), psychomotor processing speed (Salthouse, 1991), or self-reported ADL difficulty like walking upstairs (Jette et al., 2002).

A variety of factors, including social, physical, emotional, and cognitive characteristics, are associated with the ability to function independently (Galanos, Fillenbaum, Cohen, & Burchett, 1994; Galasko, 1998; Stuck et al., 1999). Among these, cognition has been shown to be a stronger predictor of impaired everyday functioning than depression severity or

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other health characteristics (Burdick et al., 2005; Christensen et al., 1999; Galanos et al., 1994). Thus, the ability to predict changes in everyday functioning using cognitive tests is an active area of research (Burton, Strauss, Hultsch, & Hunter, 2006; Cahn-Weiner, Boyle, & Malloy, 2002; Jefferson, Paul, Ozonoff, & Cohen, 2006; Royall et al., 2007; Willis, 1996). Global mental status is often measured by tests that assess multiple cognitive domains, such as the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) and the Telephone Interview for Cognitive Status (Brandt, Spencer, & Folstein, 1988). In addition to global mental status, other cognitive domains associated with everyday functioning to varying degrees include memory, executive functioning, and attention. Some of these domains, namely memory and executive functioning, may be better indicators than others of everyday functioning because they are more specific markers of mild cognitive impairment or dementia in addition to being more relevant to everyday living.

Global mental status is a strong predictor of everyday functioning (Burdick et al., 2005; Burton et al., 2006). In a critical review of existing research, Royall and colleagues (2007) reported that global measures of cognitive status explain on average 11.8% of the variance in measures of everyday functioning. However, this predictive association's magnitude could be due in part to a lack of control for specific cognitive domains that may be stronger predictors of everyday functioning (Buschke et al., 1999; Stuck et al., 1999). Particular cognitive constructs are relevant to different aspects of everyday functioning. For example, if an older adult is transported via ambulance to a hospital's emergency department, the patient's memory is important for recalling details about medical history for physicians and nurses to make educated decisions about further treatment. Going to the hospital independently requires the elderly patient to exercise executive functioning components such as judgment to realize there is an emergency and problem solving to determine transportation options.

Memory is also important for everyday functioning. Memory predictors explain on average 1.9% of the variance in everyday functioning outcomes in the review of Royall and colleagues (2007), although the Hopkins Verbal Learning Test (HVLT; Brandt & Benedict, 2001) explains considerably more variance than average (R^2 = .14). Allaire and Marsiske (2002) reported that a verbal declarative memory factor, composed of the sum of HVLT learning Trials 1, 2, and 3, is associated with everyday cognition (standardized effect size = 0.22). This factor was in turn significantly associated with self-rated everyday functioning in a sample of community-residing older adults. Although the present study does not distinguish subdomains of everyday functioning, other studies report that memory performance predicts larger proportions of variance of everyday functioning tasks that are cognitively demanding such as problem solving (R^2 = .45; McCue, Rogers, & Goldstein, 1990).

Measures of executive function, such as Part B of the Trail Making Test and tests of working memory, predict IADL impairment and subsequent dementia among older adults (Aretouli & Brandt, 2010; Bell-McGinty, Podell, Franzen, Baird, & Williams, 2002; Cahn-Weiner et al., 2002; Grigsby, Kaye, Baxter, Shetterly, & Hamman, 1998). From the review by Royall and colleagues (2007), executive function tests explain on average 6.5% of the variance in everyday functioning. However, tasks involving inductive reasoning abilities and problem solving included under the category of executive function explain more variance than other executive measures. Examples of such inductive reasoning ability measures considered in the present study are Word Series and Letter Sets tasks (Ekstrom, French, Harman, & Derman, 1976; Gonda & Schaie, 1985).

Another cognitive domain that contributes to everyday functioning is psychomotor processing speed. Processing speed refers to the time needed to process a stimulus, prepare a response, and deliver the response and is important for efficient everyday functioning (Botwinick, Brinley, & Birren, 1957; Kramer & Madden, 2008). Processing speed declines with age and is often measured in a reaction time paradigm (Salthouse, 1991). Speed of processing was a significant predictor of IADL functioning in one study of older adults (Barberger-Gateau, Fabrigoule, Rouch, Letenneur, & Dartigues, 1999). However, it was a poor predictor of everyday functioning relative to other measured cognitive domains—global cognition, executive functioning, episodic memory, and verbal ability—in a community-dwelling elderly sample (R^2 = .011; Burton et al., 2006). These conflicting findings present a gap in research that the present study hopes to address.

Few studies have examined prospective relationships between multiple cognitive domains and current (as well as changes in) everyday functioning (but see Kemper, Greiner, Marquis, Prenovost, & Mitzner, 2001; Sliwinski et al., 2006). Cross-study comparisons are challenged by the constellation of cognitive tests used to represent cognitive domains that vary in their psychometric properties. Such test differences complicate inferences about relative predictive strengths of different cognitive domains and consequently confound efforts to understand mechanisms that relate cognition and everyday functioning. Differences in study sample characteristics further complicate comparisons of predictive associations across studies (Richardson et al., 1995). The present study addresses these limitations by examining associations between everyday functioning and several cognitive domains, each comprised multiple tests. Everyday functioning is conceptualized as a single continuously distributed construct comprising a wide range of everyday activities. It is measured using validated performance-based objective measures of everyday functioning.

The Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) trial is a study of cognitive training interventions for memory, reasoning, and speed of processing in a large well-characterized sample of community-dwelling older adults. Participants have been followed for five years (Willis et al., 2006), and longitudinal data are available on measures of everyday functioning and cognition. Prior findings from ACTIVE showed a difference in everyday functioning at 5 years between the speed of processing and control groups (Willis et al., 2006), but changes or trajectories of everyday functioning have not been related to cognition. The current analyses investigate whether cognitive training interventions modify the strength of associations between cognitive domains and everyday functioning. Although baseline cognition may be associated with changes in everyday functioning, training-related changes in cognition should weaken the relationship with baseline cognition.

The present study's purpose was to examine the independent contributions of memory, inductive reasoning ability, processing speed, and global mental status in predicting both initial status and changes in everyday functioning. Consistent with prior research, it was hypothesized that global mental status, inductive reasoning, and memory would be associated with baseline level of everyday functioning and that memory, because of its relation to cognitive impairment, is critical to longitudinal changes in daily function.

METHODS

Study Sample

ACTIVE is the largest, multicenter, controlled randomized trial of cognitive training interventions among older adults to date (Ball et al., 2002; Jobe et al., 2001; Willis et al., 2006). Community-dwelling adults older than age 65 years were recruited from six metropolitan sites across the United States and assigned to receive one of three cognitive interventions: memory (n = 703), reasoning (n = 699), or speed of information processing (n = 702). A no-contact control group (n = 698) constituted a fourth group. In all, 2,802 older adults were randomized. The memory training intervention involved practicing several mnemonic strategies: organization, association, visualization, and the method of loci. Participants in the reasoning training condition were taught strategies for identifying patterns from a series of letters, words, and other symbols. Speed of processing training involved practice with divided attention and visual search paradigms that encouraged participants to reduce the time taken to search and identify objects on a computer screen. Each intervention was administered in 10 small-group training sessions, each lasting 60–75 min, conducted over six weeks. Data used in this analysis are taken from participants assessed at baseline, immediate posttest, and at 1, 2, 3, and 5 after initial training.

Outcome Measures

We investigated the influence of memory, reasoning, processing speed, and global mental status on a composite measure of everyday functioning constructed from the Everyday Problems Test (EPT), the Observed Tasks of Daily Living (OTDL), and the Timed Instrumental Activities of Daily Living test (TIADLs). The EPT is a paper and pencil test that assesses cognitive IADLs using 15 sets of comprehension tasks involving printed materials that older adults encounter in a typical day, such as reading medication labels, recipes, and telephone bills (Marsiske & Willis, 1995; Willis & Marsiske, 1993). The OTDL is a performance-based test of everyday tasks, including medication management, telephone use, and checkbook balancing (Diehl et al., 2005). The TIADL is a timed test of an individual's ability to respond correctly and quickly to common everyday stimuli, such as finding a telephone number from a telephone book, making change, and finding food items on a shelf (Ball, 2000; Owsley, Sloane, McGwin, & Ball, 2002).

A principal components analysis of baseline scores revealed that one component explains 70% of the total variance in these functioning measures. A confirmatory factor analysis further confirmed their unidimensionality in representing everyday functioning (root mean square error of approximation [RMSEA]: 0.047; comparative fit index [CFI]: 0.996). Thus, a composite index of everyday functioning was created from these tests to make inferences about everyday functioning rather than about particular tests. Each outcome was adjusted so that higher scores indicate better functioning. Component test scores were standardized at each time point to their baseline mean and standard deviation, equally weighted, and pooled together to create a continuously distributed Blom-transformed composite measure of everyday functioning (Blom, 1958).

Cognitive Predictors

Composite cognitive scores representing memory, reasoning, processing speed, and global mental status were constructed at each assessment occasion from several measures using Blom transformations. The memory construct is composed of total recall scores from modified administrations of the HVLT (Brandt & Benedict, 2001), Auditory Verbal Learning Test (Rey, 1964; Schmidt, 2004), and the Rivermead Behavioral Memory Test's paragraph recall task (Wilson, Cockburn, & Baddeley, 1985). Because alternate but nonequivalent forms were used at each time point, scores for each of these tests were adjusted using an equipercentile equating procedure (Kolen & Brennan, 1995). Reasoning is represented by the Letter Series, Word Series, and Letter Sets tasks (Ekstrom et al., 1976; Gonda & Schaie, 1985; Thurstone & Thurstone, 1949; Willis, 1996). The processing speed outcome consists of three subscales from the Useful Field of View (Owsley et al., 2002). These Blom-transformed variables have been used previously to represent cognitive domains in the ACTIVE study (Willis et al., 2006). Global mental status is represented by the MMSE (Folstein et al., 1975). The MMSE, measured at all assessment points except at immediate posttest and the first year visit, was also standardized at each visit to its baseline mean and standard deviation.

Other Covariates

Age, years of education, sex, ethnicity, and baseline self-rated health status were included in adjusted models. These variables, all measured at the baseline visit, were selected a priori because each is associated with cognition and everyday functioning (Marsiske & Willis, 1995). Age was centered at 70 years, and education was coded continuously in years and centered at 12 years.

Analysis Plan

Preliminary analyses were conducted to characterize the study sample. Parallel process latent growth models were used to examine relationships between the different cognitive variables and initial everyday functioning as well as linear trajectories of functioning (B. Muthén, 1997; L. K. Muthén & Muthén, 2008). In these models, latent factors, formed by intercepts (initial or baseline status) and slopes (trajectories or annual rates of change), represent person-specific linear growth processes for observed continuous variables measured repeatedly over time (Stull, 2008). Figure 1 shows the basic model specification. These equations describe the latent variable measurement model:

$$\text{Level 1(time)}: F_{ij} = \gamma_{0i} + \gamma_{1i}\text{time}_j + \varepsilon_i,$$

$$C_{ijm} = \eta_{im} + \varepsilon_i.$$

Level 2 (individual):

$$\gamma_{0i} = \beta_{00} + \sum_{m=1}^{4} \beta_{m0} \times \eta_{im} + \sum_{p=0}^{4} \beta_{p0} \times X_{ip} + \zeta_{i0},$$

$$\gamma_{1i} = \beta_{01} + \sum_{m=1}^{4} \beta_{m1} \times \eta_{im} + \sum_{p=0}^{4} \beta_{p1} \times X_{ip} + \zeta_{i1}.$$

In these equations, F_{ij} represents the individual-level observed everyday functioning outcome and C_{ij} represents the individual-level observed cognitive variable m (memory, reasoning, processing speed, or global cognition) for the ith individual at the jth study visit. Growth parameters γ for everyday functioning include factors for initial status and linear slope, and η_m represents the initial level or baseline level of the mth cognitive domain. These two latent variables summarize the six observed repeated measures outcomes for each growth process. Growth parameters for the intercepts and trajectories of everyday functioning are regressed on baseline cognitive scores and demographic covariates p, parameters for which are represented by β. The ε_i and ζ terms are vectors of between-person and within-person residual errors of each outcome growth process; they are assumed to be normally distributed about mean 0 and independent of one another.

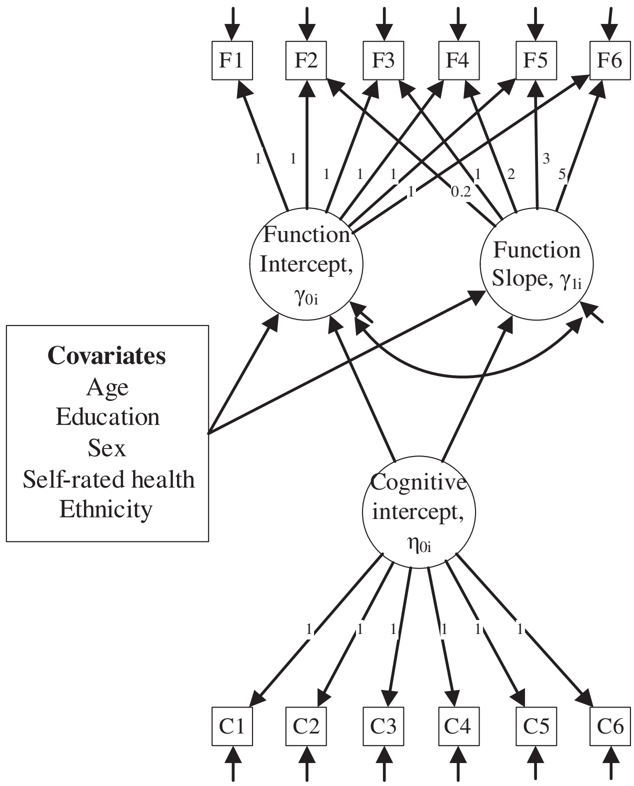

Figure 1. Parallel process latent growth model of cognition and functional ability. Parallel process latent growth model of everyday functioning and cognitive domains (memory, reasoning, processing speed, and global cognition) across six measurement occasions in the Advanced Cognitive Training for Independent and Vital Elderly study. The model is described notationally in the text. Latent variable intercepts and slopes for everyday functioning are regressed on covariates. Residual variances for the everyday functioning latent variables are shown by smaller arrows going toward the latent (circled) variables. Numbers on arrows going from latent growth parameters to observed time points indicate factor loadings. C = observed composite cognitive score at a measurement occasion. F = observed composite everyday functioning score at a measurement occasion.

In separate models for memory, reasoning, processing speed, and global cognition (the cognitive predictors), latent intercepts and slopes were estimated for both the cognitive predictor and the everyday functioning over time. In final analyses reported here, a single model containing a separate growth process for each cognitive predictor was estimated. Values for fixed time loadings on the growth parameters are written along pathways in Figure 1 to denote the spacing between each study visit. Latent growth factors for everyday functioning were regressed on the intercept growth factors for each cognitive predictor to see if initial functional status or trajectory was associated with initial cognitive ability. Growth parameters for everyday functioning were not regressed on random slopes for cognitive domains because we were interested in estimating the ability of cognition measured at baseline to predict changes in functioning, not whether changes in cognition predict changes in everyday functioning. Regression coefficients on latent variables

Table 1. Baseline Characteristics and Test Scores: Data From the ACTIVE Study (N = 2,802)

	Baseline (N = 2,802)	Immediate post-training (N = 2,562)	Year 1 (N = 2,325)	Year 2 (N = 2,234)	Year 3 (N = 2,101)	Year 5 (N = 1,877)	Observed Range
Composite cognitive scores, *M* (*SD*)							
Memory composite	−0.01 (2.30)	0.13 (2.39)	0.11 (2.50)	0.11 (2.47)	0.06 (2.55)	−0.20 (2.58)	−8.24 to 8.36
Reasoning composite	0.00 (2.66)	1.09 (2.77)	1.05 (2.71)	1.08 (2.71)	1.37 (2.78)	1.07 (2.79)	−7.69 to 10.56
Speed composite	0.00 (2.46)	−1.78 (3.14)	−1.75 (3.06)	−1.63 (2.95)	−1.80 (3.01)	−1.49 (2.88)	−8 to 4.02
MMSE (raw)	27.31 (2.01)	—	—	27.13 (2.38)	27.19 (2.37)	27.04 (2.48)	23 to 30
Everyday functioning, *M* (*SD*)							
Function composite	−0.11 (0.83)	0.00 (0.88)	0.04 (0.84)	0.08 (0.84)	0.00 (0.81)	0.01 (0.89)	−6.1 to 1.4
EPT (raw)	18.65 (5.73)	19.25 (5.61)	19.32 (5.69)	19.26 (5.60)	19.36 (5.56)	19.17 (5.77)	0 to 28
OTDL (raw)	17.58 (4.44)	—	18.65 (4.24)	19.07 (4.35)	17.98 (3.88)	18.88 (4.84)	1 to 28
TIADL (raw)	0.00 (0.61)	−0.04 (0.59)	−0.07 (0.54)	−0.09 (0.55)	−0.07 (0.57)	0.02 (0.69)	−0.86 to 5.03

Notes: Baseline predictors and observed cognitive and everyday functioning variables used in the present study. Composite scores are scaled to have mean 0 and unit variance among control participants at the baseline visit; the table shows mean scores across all intervention groups. Lower scores on the processing speed composite and TIADL test indicate better (faster) performance. ACTIVE = Advanced Cognitive Training for Independent and Vital Elderly; EPT = Everyday Problems Test; MMSE = Mini-Mental State Examination; OTDL = Observed Tasks of Daily Living; TIADL = Timed Instrumental Activities of Daily Living test.

show the predictor variable's strength in predicting the latent intercepts and slopes. Coefficients for initial functioning are standard deviation differences in initial everyday functioning for a unit change in the level of the predictor. For latent cognitive predictors, a unit change is a standard deviation change. For trajectories of everyday functioning, coefficients represent the annual standard deviation change in the everyday functioning composite for a unit change in the predictor. Squaring the standardized regression coefficients for these relationships provide a coefficient of determination (R^2; Cnaan, Laird, & Slasor, 1997). R^2 values represent covariate-specific contributions to the prediction of variance in everyday functioning outcomes (intercepts and trajectories), adjusted for other cognitive variables in the model.

The parallel process latent growth model was developed in three stages. First, a model described earlier and shown in Figure 1, without demographic covariates, was estimated for the entire ACTIVE sample, with all parameter estimates constrained to be equal across treatment groups. Coefficients of determination were calculated; significance of differences between coefficients of determination was assessed by dividing the difference in standardized regression coefficients by the standard error for that difference. In a second analysis step, the intercept and slope for everyday functioning were regressed on age, sex, ethnicity, education, and self-rated health status (Figure 1). In a third step, regressions among the latent growth factors were allowed to vary between ACTIVE treatment groups in order to compare differences in predictive strengths of cognitive variables between training groups. The question of whether regression parameters among the latent variables differed by training group was tested using a Satorra–Bentler–scaled χ^2 difference test to assess relative fit of nested models to the data (Satorra & Bentler, 1994).

Analyses were conducted using MPLUS, version 5.21 (B. Muthén & Muthén, 1998–2006). Model parameters were estimated using a robust full information maximum likelihood estimator. Residual variances of observed everyday functioning outcomes were constrained to be equal as were variances for observed cognitive variables. Overall goodness of fit was assessed with standard tests of model fit based on the χ^2 statistic, including the RMSEA (Steiger, 1989), CFI (Bentler, 1990), and the standardized root mean square residual (SRMR). An RMSEA smaller than 0.05, a CFI larger than 0.95, and an SRMR smaller than 0.08 indicate excellent model fit (Hu & Bentler, 1999).

Results

Means and standard deviations of test scores at each study visit are shown in Table 1. Baseline cognitive abilities and everyday functioning did not differ by training status. The sample is mostly female (76%) and White (73%). Participants were on average 73 years old and had a median of 12 years of education. Nearly half (44%) of the participants rated their health status as very good or excellent at baseline.

Which Cognitive Abilities Are Predictive of Everyday Functioning?

Absolute model fit was excellent for the parallel process latent growth model without covariates (Table 2). The between-persons variances of initial values and linear trajectories of everyday functioning were significant (all $p < .001$). Except in the case of global mental status, residual variances of initial status estimates were larger than variances of latent variable indicators, indicating more between-person heterogeneity than within-person variability in cognitive domains and everyday functioning. Table 2 shows independent contributions of each variable in predicting everyday functioning. This model explained 80.2% of the total variance in initial everyday functioning and 6.0% of the total variance in everyday functioning trajectories. All cognitive domains were significantly predictive of levels of everyday functioning, and all but global mental status were predictive of changes

Table 2. Predictive Associations Between Cognitive Predictors and Functional Levels and Trajectories: Data From the ACTIVE Study ($N = 2,802$)

	Unconditional model			Adjusted for demographic variables		
	β	95% CI	R^2	β	95% CI	R^2
Predictors of initial functioning level						
Memory level	0.071	(0.057, 0.085)	.042	0.056	(0.040, 0.072)	.027
Reasoning level	0.124	(0.112, 0.136)	.175	0.111	(0.099, 0.123)	.139
Speed level	−0.029	(−0.039, −0.019)	.010	−0.028	(−0.038, −0.018)	.009
Global mental status level	0.279	(0.232, 0.326)	.091	0.280	(0.233, 0.327)	.092
Demographic predictors						
Age	—			−0.008	(−0.012, −0.004)	.003
Sex (female)	—			0.069	(0.028, 0.110)	.001
Ethnicity (White)	—			0.085	(0.044, 0.126)	.002
Education	—			0.025	(0.017, 0.033)	.008
Health status	—			0.030	(−0.005, 0.065)	.000
Predictors of functioning trajectory						
Memory level	0.006	(0.002, 0.010)	.057	0.006	(0.002, 0.010)	.051
Reasoning level	−0.004	(−0.008, 0.000)	.035	−0.002	(−0.006, 0.002)	.013
Speed level	−0.004	(−0.006, −0.002)	.037	−0.003	(−0.005, −0.001)	.020
Global mental status level	−0.005	(−0.017, 0.007)	.005	−0.001	(−0.013, 0.011)	.000
Demographic predictors						
Age	—			0.000	(−0.002, 0.002)	.002
Sex (female)	—			0.004	(−0.008, 0.016)	.001
Ethnicity (White)	—			−0.013	(−0.025, −0.001)	.010
Education	—			−0.002	(−0.004, 0.000)	.012
Health status	—			−0.002	(−0.012, 0.008)	.000
Latent variable variances						
Memory level	5.016	(4.795, 5.236)		5.026	(4.817, 5.234)	
Reasoning level	6.708	(6.370, 7.046)		6.705	(6.387, 7.022)	
Speed level	6.624	(6.279, 6.969)		6.652	(6.311, 6.993)	
Global mental status level	0.690	(0.639, 0.742)		0.690	(0.639, 0.741)	
Residual variances						
Functioning indicators	0.141	(0.134, 0.147)		0.141	(0.134, 0.148)	
Memory indicators	1.120	(1.073, 1.167)		1.120	(1.073, 1.167)	
Reasoning indicators	0.798	(0.763, 0.833)		0.801	(0.766, 0.836)	
Speed indicators	2.078	(1.971, 2.186)		2.052	(1.959, 2.145)	
Global mental status indicators	0.604	(0.570, 0.638)		0.604	(0.570, 0.638)	
Initial functioning level	0.117	(0.106, 0.128)		0.111	(0.101, 0.122)	
Functioning trajectory	0.003	(0.002, 0.004)		0.003	(0.002, 0.004)	
Model fit statistics		90% CI			90% CI	
SRMR	0.052			0.045		
CFI	0.951			0.951		
RMSEA	0.053	(0.051, 0.055)		0.048	(0.046, 0.049)	

Notes: Estimates from unconditional and conditional parallel process latent growth models of cognition and everyday functioning. The model is described notationally in the analysis plan and graphically in Figure 1. Coefficients of determination (R^2) from each cognitive predictor model are shown for initial status and trajectories of everyday functioning. Standardized regression coefficients are analogous to standardized effect sizes: For initial functioning status, coefficients represent the standard deviation difference in initial functional for each standard deviation change in the predictor. For trajectories of functioning, they represent the annual rate of change in everyday functioning for a standard deviation change in the predictor. Lower scores on the processing speed composite indicate better (faster) performance. ACTIVE = Advanced Cognitive Training for Independent and Vital Elderly; CFI = comparative fit index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual; 95% CI = 95% confidence interval.

in everyday functioning. Because covariances between exogenous variables also contribute to the explanatory ability of a model in predicting an outcome as in any regression setting, a sum of the squared standardized coefficients of an outcome do not equal the total variance accounted for in the outcome. Coefficients of determination for memory, reasoning, processing speed, and global mental status were significantly different from each other for initial everyday functioning. Inductive reasoning independently accounts for the most variance in initial everyday functioning ($R^2 = .175$), followed by global mental status ($R^2 = .091$). Memory and processing speed account for only 4.2% and 1.0% of the variance, respectively (Table 2). By contrast, memory emerged as a significantly better predictor of change in everyday functioning ($R^2 = .057$) than reasoning or processing speed; the relative predictive strengths among other cognitive domains did not differ from each other in the ability to predict changes in everyday functioning (Table 2).

In a second analysis step, baseline covariates (age, sex, ethnicity, education, and self-rated health) were added to regressions of baseline and linear trajectories of everyday functioning (Table 2). Absolute model fit remained excellent. This model explained 81.0% of the total variance in initial everyday functioning and 8.9% of the total variability in functioning trajectories. Coefficients for cognitive predictors and their associated R^2 values were attenuated to varying degrees with the addition of covariates to the model, though the relative strength of predictors did not change (Table 2). Focusing on baseline demographic characteristics, being younger, female, White, and more educated was associated with a higher initial everyday functioning. No demographic characteristics were associated with linear trajectories of everyday functioning (Table 2).

When regressions among latent variable intercepts and slopes were allowed to vary across training groups in each cognitive predictor model, absolute model fit remained excellent (SRMR = 0.06; CFI = 0.931; RMSEA = 0.056, 90% confidence interval: 0.055, 0.058). A Satorra–Bentler–scaled χ^2 difference test comparing this model with a model where associations were invariant across training group was not significant ($\chi^2_{df=15} = 17.1$, $p = .32$), suggesting negligible differences in associations by training status.

Discussion

This study's objective was to investigate the predictive association of memory, reasoning, processing speed, and global mental status with performance-based measures of everyday functioning among community-dwelling older adults. Inductive reasoning emerged as the best predictor of initial functioning and memory was the best predictor of changes in everyday functioning over time. Global mental status was the second best predictor of initial functioning and a poor predictor of change in functioning. Speed of cognitive processing was the poorest independent predictor of both baseline and trajectories of everyday functioning. Cognitive training did not modify predictive strengths between cognitive domains at baseline and change in everyday functioning. The present study builds on previous research showing that various cognitive domains are, to varying degrees, predictive of concurrent everyday functioning by demonstrating that these constructs are also modestly predictive of trajectories of functioning.

One explanation why inductive reasoning and second global mental status were the top predictor of everyday functioning in this study, a pattern consistent with prior research (Burton et al., 2006; Cahn-Weiner et al., 2002; Royall et al., 2007), is that they influence abilities in other areas of cognition. Neuropsychological measures of memory and speed rely on the accuracy of information recalled or speed to complete a task (Koriat, Goldsmith, & Pansky, 2000). Executive functioning measures, which include inductive reasoning in the present study, do more than describe cognition by elucidating mechanisms underlying cognitive performance. Use of a memory strategy, for example, leads to improved memory performance. However, choosing to use the strategy from a repertoire of available techniques and executing it is not only fundamental to memory but also an integral component of executive function (Gross & Rebok, in press; Lemaire, 2010). Previous research has shown that executive functioning mediates age-related differences in memory strategy use (Taconnat et al., 2009).

A related but different interpretation of the present findings that also explains why memory and global mental status were significant predictors of initial everyday functioning along with inductive reasoning is that these cognitive domains, like performance on common IADL tasks, rely on a broad range of cognitive abilities important in everyday life (Allaire & Marsiske, 1999; Schaie & Willis, 1998; Willis, 1996). Driving, for example, is facilitated by a good memory when traveling familiar roads, whereas inductive reasoning and problem-solving functions may be more important in busy traffic conditions when decisions must be made. Driving decisions that involve reasoning capacities include avoiding adverse road conditions and deciding when to stop driving (Ball et al., 1998). Anstey, Windsor, Luszcz, and Andrews (2006) reported that reasoning ability was a significant predictor of driving cessation. All these functions, however, are highly related. Processing speed is important in everyday activities. That it was the poorest predictor of everyday functioning in the present study and elsewhere (e.g., Burton et al., 2006) may reflect that common everyday tasks do not place high enough demands on speed of cognitive processes for that domain to be as predictive of functioning as operationalized in the present study. It is also possible that older adults compensate for declines in speed by avoiding everyday tasks that place demands on processing speed.

Memory emerged as the best predictor of everyday functioning trajectories. Memory could be a more salient indicator of plasticity than other cognitive domains, or it may be more important for maintaining levels of everyday functioning, thus yielding a shallower decline or even improving trajectory of everyday functioning among older adults. Roles for memory in everyday functioning involve monitoring sequences of actions to awareness of past decisions while evaluating future decisions (Shallice & Burgess, 1996; Zanini, Rumiati, & Shallice, 2002). However, the low proportion of variance in changes of everyday functioning explained by cognitive domains suggests that cognition is not as proximal a predictor of changes in everyday functioning as are other constructs such as physical conditions or health characteristics. Further research is needed to replicate the present findings and identify better predictors of trajectories of everyday functioning.

Everyday functioning was treated as a single construct representing global IADL functioning. Exploratory analyses and a confirmatory factor analysis support this theoretical perspective, though other conceptualizations are possible. We combined measures of processing speed for completing everyday IADL tasks and everyday problem-solving tasks, for example, but other researchers might choose to treat these as different domains of everyday functioning (Allaire & Marsiske, 2002; Willis, 1996). Future research should explore a variety of conceptualizations of everyday functioning in order to evaluate the robustness of these findings. Similarly, the memory domain comprised episodic verbal learning tests, but other aspects of memory such as prospective memory (i.e., memory for future intentions) or visual memory are also relevant to everyday functioning (McDaniel & Einstein, 2007). The reasoning domain tapped only the verbal problem-solving aspects of executive function and does not fully encompass set shifting, inhibition, and goal-directed aspects. Other cognitive domains like language and visuospatial abilities have also been reported to be good predictors of everyday functioning (Hill, Backman, & Fratiglioni, 1995; Richardson et al., 1995).

One of the challenges for future research on the nature of the relationship between cognitive domains and everyday functioning will be to explore the nature of the association between cognition and everyday functioning and whether relations are causal or correlational. The present study found no moderating effects of training on predictive associations between baseline cognitive domains and change in everyday functioning, suggesting that training-related changes in cognition attributable to ACTIVE training did not attenuate the relationship between baseline cognition and everyday functioning. Another interpretation is that members of the study cohort did not show large enough changes in everyday functioning to observe changes in associations with cognitive domains. Additionally, although cognitive domains are statistically significant predictors in the present study, they only account for a portion of the total variability in everyday functioning.

Several limitations of this research are important to mention. The study is correlative in nature but consistent with prior research. To the degree that the model is underspecified or there are confounding factors, different findings could result. ACTIVE consisted of community volunteers who were screened to exclude persons with serious medical and neurologic disease. Although the ACTIVE study is a large sample of community-dwelling older adults from around the United States, our pattern of findings may not generalize to a sample that includes a higher prevalence of older adults with ill health or dementia. One recent study, for example, showed that in a sample of cognitive healthy and mild cognitively impaired older adults, noncontent memory measures (prospective, temporal order, and source memory) emerged as the best predictors of IADL performance (Schmitter-Edgecombe, Woo, & Greeley, 2009).

Despite these limitations, an important strength of this study is that ACTIVE is a large diverse sample of older adults. As a result, our findings should be generalizable to older community-dwelling adults. Second, coefficients of determination for everyday functioning intercepts and slopes were derived through latent variable regressions in a structural equation modeling framework, which reduces random measurement error. Multiple measures for the exposure and outcome provide robust support for the findings, and because latent variables are assumed to be without measurement error, our estimates are presumably less attenuated by error than are observed measures. Everyday functioning and cognitive domains were constructed from a rich source of objective performance-based tasks. This approach emphasizes the roles of underlying cognitive domains predicting everyday functioning rather than of particular test performance. Measures should consequently be less susceptible to chance variation or idiosyncrasies of particular instruments, such as the method of administration or content validity (e.g., Burton et al., 2006).

This study has important implications. Older adults characteristically show wide variability in everyday functioning, and clinicians are often asked about a patient's ability to function independently in community settings. Although brief measures of global mental status such as the MMSE are practical and already common in research and clinical settings, tests from specific cognitive domains are also well-tolerated, quick to administer, not resource intensive, and may better predict levels of and changes in everyday functioning than global measures. For memory, the HVLT in particular is a relatively brief, easy test to administer, and perhaps better tolerated by patients than other memory tests (Brandt & Benedict, 2001). Inductive reasoning, as measured by Letter Series, Word Series, and Letter Sets tasks, is the most robust indicator of concurrent functioning. New learning and memory are the best predictor of changes in everyday functioning over five years. Future research is needed to replicate the findings among more disabled older adults as well as those with more longitudinally observed functional decline.

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Conflicts of Interest

Dr. G. W. Rebok is a consultant for Compact Disc Incorporated, which is at this time in the process of developing an electronic version of the ACTIVE memory training program. He has received no financial support from them for ACTIVE. Dr. J. Brandt receives royalty income from Psychological Assessment Resources, Inc., on sales of the HVLT-Revised. Drs. G. W. Rebok's and J. Brandt's relationships are managed by the Johns Hopkins University according to its established conflict of interest policies. Inferences expressed here are those of the authors and are not reflective of the academic or funding agencies involved.

Correspondence

Correspondence should be addressed to Alden L. Gross, PhD, MHS, Department of Mental Health, Johns Hopkins Bloomberg School of Public Health, 798 Hampton House, 624 N. Broadway, Baltimore, MD 21205. E-mail: aldengross@hsl.harvard.edu.

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