Published in final edited form as:

Neuropsychology. 2014 November ; 28(6): 881–893. doi:10.1037/neu0000109.

Assessment of Functional Change and Cognitive Correlates in the Progression from Healthy Cognitive Aging to Dementia

Maureen Schmitter-Edgecombe, Ph.D. and Carolyn M. Parsey, M.S.

Department of Psychology, Washington State University, Pullman, Washington

Abstract

Objective—There is currently limited understanding of the course of change in everyday functioning that occurs with normal aging and dementia. To better characterize the nature of this change, we evaluated the types of errors made by participants as they performed everyday tasks in a naturalistic environment.

Method—Participants included cognitively healthy younger adults (YA; $N = 55$) and older adults (OA; $N = 88$), and individuals with mild cognitive impairment (MCI; $N = 55$) and dementia ($N = 18$). Participants performed eight scripted everyday activities (e.g., filling a medication dispenser) while under direct observation in a campus apartment. Task performances were coded for the following errors: inefficient actions, omissions, substitutions, and irrelevant actions.

Results—Performance accuracy decreased with age and level of cognitive impairment. Relative to the YAs, the OA group exhibited more inefficient actions which were linked to performance on neuropsychological measures of executive functioning. Relative to the OAs, the MCI group committed significantly more omission errors which were strongly linked to performance on memory measures. All error types were significantly more prominent in individuals with dementia. Omission errors uniquely predicted everyday functional status as measured by both informant-report and a performance-based measure.

Conclusions—These findings suggest that in the progression from healthy aging to MCI, everyday task difficulties may evolve from task inefficiencies to task omission errors, leading to inaccuracies in task completion that are recognized by knowledgeable informants. Continued decline in cognitive functioning then leads to more substantial everyday errors, which compromise ability to live independently.

Keywords

activities of daily living; mild cognitive impairment; memory; executive functioning; dementia

The population is aging, with the estimated number of individuals over the age of 85 expected to triple by 2050 (Vincent & Velkoff, 2010). Currently 50% of adults age 85+ need assistance with everyday activities, with one in three households anticipated to have at least one family member with cognitive decline within the next decade (Alzheimer's Association,

2012). Although researchers have documented that instrumental activities of daily living (IADL; e.g., using the telephone, preparing meals, taking medications, and managing finances) are affected earlier in dementia relative to basic self-care tasks (e.g., bathing, dressing, toileting, transferring, and feeding), the course of functional change that occurs between aging and dementia remains undefined (Farias et al., 2006; Perneckzy et al., 2006; Tam, Lam, Chiu, & Lui, 2007). Understanding the course of functional change and developing methods for both prevention and early intervention have significant health care implications for the aging population. In this study, we characterize the nature of everyday functional deficits in healthy aging, mild cognitive impairment (MCI), and dementia populations by using a naturalistic observation task to evaluate the nature of everyday task errors and concomitant cognitive correlates.

It has been argued that evaluating individuals in their everyday environment provides the most valid determination of everyday functional status, especially when observing subtle changes in behaviors across extended periods of time (Marcotte, Scott, Kamat, & Heaton, 2010). In the field of neuropsychology, informant-report and performance-based measures have been used most commonly as proxies for real-world functioning as they exhibit stronger relationships with objective cognitive decline than self-report measures (e.g., Miller, Brown, Mitchell, & Williamson, 2013; Mitchell et al., 2011; Tsang, Diamond, Mowszowski, Lewis, & Naismith, 2012). Although informant-report and performance-based methods do not always correlate highly with each other (e.g., Burton, Strauss, Bunce, Hunter, & Hultsch, 2009; Finlayson, Havens, Holm, & Van Denend, 2003; Jefferson et al., 2008; Loewenstein et al., 2001; Schmitter-Edgecombe, Parsey, & Cook, 2011; Tabert et al., 2002), both methods suggest that advanced age is a risk factor for functional impairment and that individuals with MCI have subtle deficits in everyday activities that extend beyond those of cognitively healthy older adults (e.g., De Vriendt et al., 2012; Jefferson et al., 2008; Schmitter-Edgecombe et al., 2011; Yeh et al., 2011). Data from both methods also suggest that the ability to manage finances may be among the earliest IADL changes in MCI (Gold, 2012). However, both types of methods have limited sensitivity for capturing more nuanced performance difficulties. More specifically, performance-based measures typically provide an overall accuracy score reflecting a participant's ability in one or more IADL domains (e.g., medication management, finances), while informant-based measures generally consist of rating whether an individual is able to complete a task (e.g., shopping) either independently or with some degree of help. Increased sensitivity in measurement would foster a better understanding of the course of functional change between aging and dementia.

Only a few published neuropsychological studies have directly observed individuals with MCI or dementia completing complex activities of daily living (e.g., making toast and coffee, dressing, preparing for a day out, driving) and coded activity completion for detailed error types (e.g., Bailey, Kurby, Giovannetti, & Zacks, 2013; Feyereisen, 1999; Giovannetti et al., 2008a; Giovannetti et al., 2008b; Griffith et al., 2003; Okonkwo, Wadley, Griffith, Ball, & Marson, 2006; Schmitter-Edgecombe, McAlister, & Weakley, 2012; Seidel et al., 2013; Wadley et al., 2009). Importantly, these studies have begun to inform our understanding of underlying everyday performance difficulties. For example, Feyereisen (1999) found that when the dressing performance of patients with Alzheimer's disease (AD)

was only mildly impaired, unsatisfactory executions and incorrect choices of clothing were the most common errors. However, more severely impaired patients demonstrated passivity as well as scattered gestures, irrelevant verbalizations, unrelated motor activity, and declaration of inability without trying. In addition, research with the Financial Capacity Instrument has shown that patients with mild AD have deficits across nearly all aspects of financial capacity (Martin et al., 2008), whereas individuals with MCI have more difficulty with conceptual understanding of finances (e.g., bank statement management, bill payment) and relatively preserved procedural skills (e.g., cash transactions; Okonkwo et al., 2006).

Several recent studies have used the Naturalistic Action Test (NAT; Schwartz, Buxbaum, Ferraro, Veramonti, & Segal, 2003; Schwartz, Segal, Veramonti, Ferraro, & Buxbaum, 2002) to evaluate relationships between everyday action errors and cognitive and neuroanatomical correlates (Bailey et al., 2013; Giovannetti et al., 2006; 2008a; 2008b; Seligman et al., 2014). During the NAT, participants are seated at a semi-circular table that contains everyday objects and required to complete multi-step naturalistic actions in order to achieve a goal (e.g., make toast and coffee, pack a lunchbox). Mild AD patients were found to commit more total errors on the NAT compared to individuals with MCI who made more errors than healthy controls (Giovannetti et al., 2008b). Furthermore, the number of commission errors (i.e., performing task steps inaccurately) committed by the control and MCI participants was higher than the number of omission errors (i.e., not completing a task step), whereas the AD patients showed an equivalent number of commission and omission errors.

Additional studies by Giovannetti and colleagues further suggest that NAT omission and commission errors may represent distinct components of everyday action performance (Giovannetti et al., 2008b; Seidel et al., 2013). More specifically, in an AD sample the failure to perform task steps (i.e., omission errors) was associated with episodic memory deficits and reduced volume of the hippocampus and medial temporal lobe, whereas inaccuracies in completing task steps (i.e., commission errors) were predicted by executive dysfunction and associated with decreased volume in deep white matter and in the dorsolateral prefrontal cortex (Bailey et al., 2013; Giovannetti et al., 2008b; Seidel et al., 2013). A third category, termed “off-task commissions” or “action addition errors” (i.e., performance task steps that were inconsistent with the task), correlated with smaller volumes of both white matter and gray matter structures (Seidel et al., 2013) and with the anterior cingulate cortex volume (Bailey et al., 2013) in a dementia population. These findings, along with other recent findings (e.g., Nadkarni, Levy-Cooperman, & Black, 2012), suggest that different error components of IADLs may be related to specific cognitive functions and brain regions.

Recent research that required healthy young adults (YAs) and older adults (OAs) as well as individuals with MCI to complete complex, open-ended tasks (i.e., day out task [DOT] and Map task) in a simulated home environment also suggests that different error types may be related to specific cognitive domains and differentially characterize participant groups (McAlister & Schmitter-Edgecombe, 2013; Sanders & Schmitter-Edgecombe, 2012; Schmitter-Edgecombe et al., 2012). More specifically, research with the DOT (i.e., a task that requires participants to multi-task and interweave eight tasks that an individual might

complete when preparing for a day out) found that healthy OAs made more sequencing errors and completed more of the DOT subtasks inefficiently compared to YAs, and the OA difficulties were associated with executive functions (McAlister & Schmitter-Edgecombe, 2013). Other work revealed that although individuals with MCI approached the DOT in a manner similar to OAs, significantly more subtasks were completed incompletely and inaccurately by individuals with MCI and these difficulties were associated with episodic memory abilities (Schmitter-Edgecombe et al., 2012).

One goal of the present study was to identify and describe the types of errors that define normal aging difficulties with IADLs, and then characterize the types of deficits that occur with transition to MCI and to dementia. We report on behavioral observation data collected while healthy YA and OA controls, as well as individuals with MCI and dementia completed activities of daily living in a campus apartment. The apartment consisted of a kitchen, living room, and dining room on the ground floor. The observed behaviors included eight, highly-scripted complex activities (e.g., locate and fill a medication dispenser; prepare a cup of noodle soup) that were performed once by the participant. Participant performances were coded for four different error types, including inefficient actions, omissions, substitutions, and irrelevant actions. Although the on-campus apartment presented a unique opportunity to collect direct behavioral observation data within a naturalistic environment, participants were not tested in their own homes nor were repeated measurements of the same everyday activities collected.

We also examined the contribution of executive and memory abilities to specific error types. We hypothesized that OAs would exhibit more inefficient actions than YAs, and that the performance of MCI and dementia participants would be characterized by additional errors in omission. Based on prior findings (e.g., Bailey et al., 2013; Giovannetti et al., 2008b; Schmitter-Edgecombe et al., 2012), we hypothesized that omission errors would be closely tied with memory abilities, while task inefficient behaviors (e.g., searching, sequencing difficulties, task additions) would be more highly correlated with executive functioning. In addition, to determine which specific error type(s) best predicted everyday performance as measured by common proxy measures of functional status, we evaluated the relationship between error types and an informant-report and performance-based measure [i.e., Everyday Problems Test (EPT), Willis & Marsiske, 1993] of functional status. Given that omission errors were expected to characterize the performance of individuals with MCI and dementia most distinctly, we hypothesized that omission errors would be most associated with performance on the proxy measures of functional status.

Method

Participants

Participants were 53 younger adults, 88 cognitively healthy OAs, 55 individuals with MCI, and 18 individuals with dementia. Younger adult participants were recruited through the Department of Psychology subject pool. The older adult participants were recruited from the community through advertisements, community health and wellness fairs, physician referrals, referrals from local agencies working primarily with older adults, and from past studies in our laboratory.

Older adult participants completed a medical interview screening over the phone to rule out the following exclusion criteria: history of head trauma with a period of coma, current or recent (past year) psychoactive substance abuse, history of cerebrovascular accidents, or other known medical, neurological or psychiatric causes of cognitive dysfunction (e.g., epilepsy, Lewy body dementia). The Telephone Interview for Cognitive Status (TICS; Brandt & Folstein, 1993) was administered to exclude individuals with significant cognitive impairment who therefore could not complete the laboratory assessment. Participants were also excluded if they endorsed symptoms suggestive of significant depression as evidenced by a Geriatric Depression Scale (GDS) - Short Form (Sheikh & Yesavage, 1986) score > 10. The Clinical Dementia Rating (CDR; Hughes, Berg, Danzinger, Coben, & Martin, 1982; Morris, 1993; Morris et al., 1991) instrument was also administered by a certified examiner to the older adult participants and a knowledgeable informant to assess dementia staging.

Diagnostic groups (i.e., healthy OA, MCI, and dementia) were determined by performances on neuropsychological tests, CDR ratings, participant and informant interview data, and medical records when available (e.g., brain imaging, previous neuropsychological assessments). The eight activities direct observation measure examined in this study was not used in clinical diagnosis. Materials were carefully reviewed by two experienced neuropsychologists who determined diagnostic groups. Healthy OA participants denied a history of cognitive changes, scored a 0 on the CDR, and performed within normal limits on the TICS (age and education taken into consideration). Participants with dementia met the *Diagnostic and Statistical Manual of Mental Disorders (DSM-IV)* dementia criteria (American Psychiatric Association, 2000). These criteria included report of gradual onset and decline from a prior higher level of functioning, as well as objective evidence of deficit in two or more cognitive domains with significant impact on everyday functioning as documented by the CDR and self and informant interview data. Inclusion criteria for MCI were consistent with the criteria defined by Petersen and colleagues (Petersen et al., 2001; Petersen & Morris, 2005). These criteria included (a) self- or informant-report of memory impairment for at least 6 months; (b) objective evidence of impairment as determined by cognitive test scores falling at least 1.5 standard deviations below appropriate norms or in comparison to prior data; (c) nonfulfillment of DMS-IV dementia criteria (d) preserved general cognitive functions as determined by TICS score within normal limits; and (e) no significant deficits in everyday activity completion as confirmed by a total CDR score no greater than 0.5. The majority of participants met criteria for amnesic MCI (87%). In addition, participants with both single-domain (35%) and multi-domain (65%) MCI (speeded processing, memory, language, and/or executive functioning) are represented in this sample. We excluded from study analysis, participants who could not confidently be classified as healthy OA, MCI or dementia. For example, if a participant had a CDR of 0.5 (questionable dementia) but did not meet other criteria for MCI, they were excluded from the study.

All participants who met initial screening criteria completed a battery of standardized and experimental neuropsychological tests in a laboratory, as well as a variety of complex activities of daily living (e.g., filling a medication holder) within an apartment located on the WSU campus. These evaluations were scheduled one week apart with each testing session

lasting approximately 3 hours. All data was scored following the second session. The MCI and dementia participants were matched closely with the healthy older adult sample in terms of age and education (see Table 1). Because this study was conducted as part of a larger study (Schmitter-Edgecombe et al., 2011), the OA control group represents a subsample of the 168 healthy older adults who best demographically matched the MCI and dementia participants. In addition, evaluation of the direct observation total accuracy score and cognitive correlates (no error analysis) was reported for a subset of the healthy older adults and individuals with MCI in a recent paper (Schmitter-Edgecombe & Parsey, in press). All older adult participants were given a report documenting their performance on the neuropsychological tests, as well as pre-paid parking passes, as compensation for their time. Participants who traveled to the laboratory from outside Whitman or Latah County were also provided a \$50 voucher for travel reimbursement. Younger adult participants received course credit for their participation. This protocol was reviewed and approved by the Institutional Review Board at WSU.

Measures

Functional Status Measures—Current capacity of everyday functioning was captured by direct observation of IADLs in a campus apartment at WSU (see Schmitter-Edgecombe et al., 2011 for additional details). Other proxy measures of functional status included an informant-report measure and a performance-based measure (i.e., EPT).

Direct Observation Task (8 IADLs): Participants completed a direct observation task that included eight activities of daily living within a campus apartment. A brief description of each of these activities is included below (for additional details about required completion steps for each activity and data collection procedures see Schmitter-Edgecombe et al., 2011).

1. *Sweeping and dusting:* Participants were instructed to retrieve a broom, dustpan/brush, and duster from a supply closet. They were then to sweep the kitchen floor, dust the furniture in the living and dining rooms, and return items to the supply closet.
2. *Medication dispenser:* Participants were instructed to fill a 7-day pill holder using three bottles of different medications. Written directions, which were taped to the kitchen cupboard door where the pill holder and medication bottles were located, indicated the weekly medication “regimen.”
3. *Birthday card and check:* Participants were instructed to retrieve a birthday card, envelope, and blank check. They were to fill out these items as if they were sending a monetary birthday gift to a close friend or relative.
4. *Watching a DVD:* Participants were instructed to retrieve a DVD containing a 5-minute video clip from “Good Morning America.” This task required operating the DVD player and watching the entirety of the news clip.
5. *Watering houseplants:* Participants were instructed to retrieve a watering can from the supply closet and water three houseplants located in the living room and kitchen. Any extra water was to be dumped in the sink and the watering can returned to the supply closet.

6. *Phone call*: Participants were to answer a ringing telephone, converse with the experimenter by answering questions about the news clip from the DVD task, and then hang up the telephone.
7. *Cooking soup*: Participants were instructed to retrieve a microwaveable cup of noodle soup and follow the microwave cooking directions on the packaging. In addition, they were to pour a glass of water and bring the soup and water glass to the dining room table.
8. *Outfit selection*: Participants were instructed to retrieve an appropriate job interview outfit for a male friend. Items were to be chosen among distractor items in a closet and, once selected, laid out on the couch.

Experimenters provided brief verbal instructions prior to each task. Using the materials provided in the apartment, participants carried out each activity. During each activity two experimenters, who were trained research assistants from our laboratory, observed the participant and recorded task completion time, the sequence of completed steps and task errors. Task errors were then coded by two independent raters, who were trained research assistants in our laboratory and blind to the cognitive status of the participant. Video recordings of participants performing the tasks were also available for review. The following four error types were coded: inefficient actions, omissions (critical and non-critical omissions), substitutions (critical and non-critical substitutions), and irrelevant actions. Table 2 contains descriptions of each of the error types as well as the scoring rubric for deriving the overall activity score for each activity. The eight activity scores were summed to derive the total accuracy score. In addition, the time to complete each task was obtained during the assessment, and these eight times were summed for a total task completion time.

Regarding reliability of coding procedures, activities were coded individually using a list of potential errors associated directly with task steps. As new errors were observed for each activity they were added to the working document of errors for the particular task step. Scorers discussed and resolved discrepancies in coding when necessary. Initial agreement was 91.62% for inefficient errors, 94.88% for omission errors, 92.21% for substitution errors, and 92.46% for irrelevant errors. Overall agreement for the direct observation total score was 92.33%. A prior study from our laboratory (Schmitter-Edgecombe et al., 2011) that discussed development of the eight activities direct observation task found similar agreement between trained raters (range = 95.45%-97.79%). In addition, poorer overall performance (i.e., total score) on the Direct Observation task was associated with increased age in cognitively-healthy older adults, and correlated significantly with both a self-report and a performance-based measure of functional status (Schmitter-Edgecombe et al., 2011).

Knowledgeable Informant Report about IADLs: A knowledgeable informant for each participant completed a 50-question interview about current IADL capacities of the participant (Schmitter-Edgecombe et al., 2012). Ten IADL domains were assessed, including using the phone, traveling, shopping, preparing meals, household activities, conversation, organization, social functioning, medication management, and financial management. Items were based on Likert-scale responses, ranging from 1 (independent, complete task as well as ever, uses no aid to assist) to 8 (unable to complete activity

any more). “Does not need to complete the activity” and “no basis for judgment” were additional response options. An average of the 50 responses was used as a total score for knowledgeable informant report of IADL skills.

Performance-based IADL Measure: The EPT (Willis & Marsiske, 1993) is a performance-based paper-and pencil task of everyday competency and knowledge. Participants are tasked with solving problems that simulate daily experiences (e.g., reading a recipe). The participant uses the provided stimuli to answer six multiple choice questions relevant to different IADLs. The following four IADLs were assessed: shopping, transportation, household activities, and meal preparation. Correct responses were summed for a total EPT score (maximum score = 24).

Cognitive Test Variables—Cognitive predictor variables were derived from standardized neuropsychological tests assessing cognitive domains that have successfully predicted functional status in previous studies (e.g., Farias et al., 2006; Mariani et al., 2008), including global cognitive status, processing speed, memory, and executive functioning.

Telephone Interview for Cognitive Status (TICS; Brandt & Folstein, 2003): Global cognitive functioning was determined by the total score from this telephone-based mental status exam.

Symbol Digits Modalities Test, Oral Subtest (SDMT oral; Smith, 1991): Processing speed was measured using the total score (items completed correctly within 90 seconds) from the SDMT. Performance on the oral version was used to eliminate the influence of health-related variables (e.g., arthritis) that may compromise motor speed.

Memory Assessment Scale (MAS) - List Learning subtest (Williams, 1991): Verbal memory was measured using the number of words recalled from a word list after a long delay (maximum = 12 words).

Brief Visuospatial Memory Test – Revised (BVM-T-R) Delayed Recall (Benedict, Schretlen, Groninger, Dobraski, & Shpritz, 1996): Visual memory was measured using the total score from the delayed recall subtest of the BVM-T-R (maximum = 12 points; 6 for placement, 6 for accuracy).

Delis-Kaplan Executive Function System (D-KEFS) - Letter Fluency and Design Fluency subtests (Delis, Kaplan, & Kramer, 2001): Executive functioning was measured using the total number of words produced for letters F, A, and S (Letter Fluency) and total number of correct designs produced over three trials (Design Fluency).

Results

Analyses

All variables were evaluated for normality before conducting parametric statistics. The four activity error type scores (i.e., inefficient actions, omissions, substitutions, and irrelevant actions) required square-root transformations to correct for non-normal distributions. All

error type analyses used the transformed variables; however, non-transformed values are presented in the Tables and the Figure for ease of interpretation. One-way Analyses of Variance (ANOVAs) were used to compare the performance of the YAs, OAs, and individuals with MCI and dementia on the neuropsychological and IADL measures. When group differences were found ($p < .05$), Scheffe post hoc comparisons were conducted. Stepwise discriminant function analyses were also conducted to determine which error types best discriminated between diagnostic groups. Hierarchical regression analyses were used to examine how well memory and executive functioning measures predicted the different error types. General cognitive functioning and demographic factors that correlated significantly with the error types were controlled for in the first step of the regression model. Hierarchical regression modeling was also used to examine which error types best predicted performance on proxy measures of functional status (i.e., informant-report and EPT).

Demographic and Neuropsychological Data

Table 1 shows the demographic and neuropsychological testing data for the YA, OA, MCI, and dementia groups. There was no significant difference among the four groups in years of education, $F(3, 198) = 1.57, p = .20$, and the three older adult groups (i.e., OAs, MCI and dementia) were matched in age, $F(2, 158) = 1.27, p = .28$. The dementia group had a higher proportion of male participants than the other three groups, $\chi^2(214) = 15.46, p = .001$, which did not differ in gender distribution, $\chi^2(196) = 4.65, p = .10$. Although self-reported symptoms of depression were low, the MCI group self-reported significantly more depressed mood symptoms relative to the OA and dementia groups. In addition, as seen in Table 1, the dementia group performed more poorly than the YA, OA and MCI groups on all cognitive tests administered. With the exception of the TICS total score, the MCI group performed more poorly than the OA control group on the measures of processing speed, verbal and visual memory, and executive skills. Consistent with the normal aging process, the OA controls performed more poorly than the YAs on measures of speeded processing and visual memory. Significant differences in executive functioning between the OA and YA group were observed on the D-KEFS design fluency subtest, but did not achieve significance on the D-KEFS letter fluency subtest.

Direct Observation Task (8 IADLs)

The means and standard deviations for total time to complete the eight activities task and overall task accuracy can be found in Table 3. Because there were no gender differences in performance across the eight activity measures for each of the four groups, $t's < 1.92, p's > .06$, gender was not considered as a covariate in the analyses. One-way ANOVAs revealed that the groups differed in total time to complete the eight activities, $F(3, 210) = 15.31, p < .001$, and in total accuracy, $F(3, 210) = 53.44, p < .001$. As seen in Table 2, Scheffe post hoc comparisons revealed that the YAs completed the eight tasks faster than all three older adult groups. However, the OA, MCI, and dementia groups did not differ significantly from each other in time to complete the tasks. The total accuracy score revealed poorer IADL completion performances as age and level of cognitive impairment increased, such that $YA > OA > MCI > dementia$.

To better understand the nature of the difficulties reflected in the overall accuracy score, one-way ANOVAs were conducted on the error type data. Significant group differences were found for each of the four error types: inefficient actions, $F(3, 210) = 26.66, p < .001$, omissions, $F(3, 210) = 37.39, p < .001$, substitutions, $F(3, 210) = 23.57, p < .001$, and irrelevant actions, $F(3, 210) = 2.09, p = .002$. As shown in Figure 1, Scheffe post hoc comparisons revealed that the YAs made significantly fewer errors characterized by task inefficiencies ($M = .58$) when compared to the older adult groups. The OA ($M = 2.03$) and MCI ($M = 2.84$) groups did not differ in the number of inefficient actions, and both groups had significantly fewer inefficient actions than the dementia group ($M = 4.80$). The dementia group ($M = 10.36$) committed more errors of omission than the MCI group ($M = 4.45$), who committed more errors of omission than both the YA ($M = 2.21$) and OA ($M = 2.13$) groups. The YA and OA groups did not differ in omission errors. The dementia group ($M = 2.72$) also committed significantly more substitution errors than the YA ($M = .38$), OA ($M = .68$), and MCI ($M = 1.15$) groups. Substitution errors were also significantly greater for the MCI group compared to the YA group; the substitution errors of the OA group did not differ significantly from either the YA or MCI group. Finally, the number of irrelevant actions committed was greater for the dementia group ($M = 1.80$) compared to the YA ($M = .40$) and OA ($M = .52$) groups. The number of irrelevant actions committed by the MCI group ($M = 1.80$) did not differ significantly from any of the other groups. Taken together, these data suggest that the error performance of the OA controls was best characterized by inefficient actions, whereas omissions were significantly more frequent in the MCI group, and the dementia group experienced considerable difficulties across all error types.

Discriminant Analyses

Stepwise discriminant function analyses were also completed to identify the error types (i.e., inefficient actions, omissions, substitutions, irrelevant actions) that best discriminated between the YA and OA groups, OA and MCI groups, and MCI and dementia groups. Findings were consistent with the ANOVA analysis. More specifically, inefficiencies emerged as the only predictor that entered into the equation that discriminated the YAs and OAs, Wilks' lambda = .742, $p < .001$, with a classification correctness rate of 77.3%. In contrast, for the OA and MCI discriminant function analysis, omissions emerged as the only predictor entering the equation, Wilks' lambda = .917, $p < .001$, with a classification correctness rate of 61.5%. Both omission errors, Wilks' lambda = .801, $p < .001$, and substitutions errors, Wilks' lambda = .752, $p < .001$, entered into the equation that discriminated the MCI and dementia groups, with a classification correctness rate of 68.5%. Furthermore, using all 4 predictors in the discriminant function analysis did not increase the classification rate by more than 4% for any of the group discriminations.

Regression Analyses: Cognitive Determinants

Hierarchical regression analyses were conducted to examine cognitive predictors for each of the error types. To increase statistical power and the range of variation, the OA, MCI, and dementia groups were combined for the regression analyses. Recently it has been argued that this approach is more effective than a single diagnostic group approach for evaluating functional heterogeneity in older adults (Seligman et al., 2014). Combining the groups also allowed us to examine the role of memory and executive functioning abilities in the

transition from normal to impaired performance. The sample size for the regression analyses was reduced by 14 participants ($n = 147$) as several of the participants (8 dementia, 3 MCI, and 3 OA) did not have complete data for one or more of the cognitive predictors.

Before conducting the regression analyses, correlations among the four coded error types were explored, with age and general cognitive status (i.e., TICS) held constant. Given the number of correlations being conducted, a more conservative p -value of .01 was used for significance. As seen in Table 4, significant small to moderate positive correlations emerged between omissions and substitutions ($r = .33, p < .001$) and between inefficient actions and irrelevant actions ($r = .22, p = .007$). No other correlations among the criterion variables reached statistical significance, suggesting dissociation among the error type measures.

Correlations among the error type measures and predictor variables are shown in Table 5. To reduce the number of demographic predictors (i.e., age, education, gender, and depression), we assessed for relationships between the demographic and criterion variables. Because age was the only demographic factor that correlated significantly with error type (i.e., inefficient actions and omissions), it was entered in the first step of the regression model along with the total TICS score (i.e., global cognitive functioning measures) and a measure of processing speed (i.e., SDMT oral), which were both used to control for general cognitive functioning. To determine whether memory and executive functioning deficits differentially predicted error types, the regression analyses were first completed by entering the memory measures (i.e., MAS list delayed recall and BVMT-R delayed recall) into the second step followed by the executive functioning measures (i.e., D-KEFS letter fluency and design fluency subtests) in the third step. The regression analyses were then repeated with the executive functioning measure entered in the second step followed by the memory measures in the third step. There was no significant multi-collinearity among the seven predictor variables (Variance Inflation Factors < 2.42). Regression model data can be found in Table 6.

For inefficient actions, we were interested in whether executive functions would account for additional variance after controlling for memory abilities. The analyses revealed that the memory measures (variance accounted for represented by R^2) did not account for significant variance above and beyond that explained by age and general cognitive functioning (i.e., TICS and SDMT oral) when they were entered in the second block of the regression analysis [$R^2 = .01, F(2, 141) = .992, p = .37$; total $R^2 = .20$]. However, when the executive functioning measures were added into the third block, the amount of additional variance explained by executive abilities nearly reached significance [$R^2 = .03, F(2, 139) = 2.92, p = .058$; total $R^2 = .23$]. Furthermore, both the TICS total score, $B = -.21, t = -2.33, p = .021$, and the D-KEFS design fluency measure, $B = -.25, t = -2.41, p = .017$, emerged as unique predictors of inefficient actions in the final model.

For omission errors, we were interested in whether memory would account for additional variance after controlling for executive abilities. When the executive functioning measures were entered into the second block, the measures did not account for significant variance above and beyond variance explained by age and general cognitive functioning (i.e., TICS and SDMT oral), [$R^2 = .00, F(2, 141) = .064, p = .94$; total $R^2 = .40$]. As hypothesized, when the memory measures were added into the third block, the memory measures

explained a significant amount of additional variance [$R^2 = .09$, $F(2, 139) = 13.42$, $p < .001$; total $R^2 = .50$]. The scores for the SDMT oral, $B = -.30$, $t = -3.18$, $p = .002$, and the MAS list delayed recall, $B = -.28$, $t = -3.32$, $p = .001$, emerged as unique predictors of omission errors in the final model.

The regression model for substitution errors revealed that neither the executive functioning [$R^2 = .02$, $F(2, 141) = 2.05$, $p = .13$; total $R^2 = .20$] nor the memory measures [$R^2 = .03$, $F(2, 141) = 2.49$, $p = .09$; total $R^2 = .21$] accounted for significant variance beyond that explained by age and general cognitive functioning when they were entered into the second block of the regression analyses. Consistent with this, only the TICS total score, $B = -.23$, $t = -2.46$, $p = .015$, emerged as a unique predictor of substitution errors in the final model. The regression models for irrelevant actions revealed no significant changes in R^2 and no significant unique predictors, likely reflecting the overall low frequency of irrelevant actions that primarily occurred in the more impaired dementia participants (see Table 6).

Regression Analyses: Functional Outcome

Additional regression analyses were conducted to determine which types of errors were most predictive of informant report and performance-based (i.e., EPT) measures of everyday functional status. Similar to the regressions above, age and general cognitive function (i.e., TICS and SDMT oral) were controlled for in the first step. In the first regression, the four error type variables were entered simultaneously into the second step (Variance Inflation factors < 2.09). The error type measures accounted for significant variance in informant report above and beyond the variance explained by age and general cognitive functioning, [$R^2 = .21$, $F(4, 107) = 9.77$, $p < .001$; total $R^2 = .42$]. Omission errors, $B = .43$, $t = 4.07$, $p < .001$, substitution errors, $B = .21$, $t = -2.57$, $p = .011$, and the TICS total score, $B = -.21$, $t = -2.27$, $p = .025$, emerged as unique predictors of informant report. The error type measures also accounted for significant variance above and beyond the variance explained by age and general cognitive functioning, [$R^2 = .10$, $F(4, 121) = 4.17$, $p = .003$; total $R^2 = .30$] for the EPT. Omission errors, $B = -.31$, $t = -3.04$, $p = .003$, emerged as the only unique predictor for the EPT.

The regression analyses were then rerun with the measures of executive functioning and memory entered in the second step followed by the error type measures in the third block. For informant report, the error type measures continued to account for additional significant variance, [$R^2 = .10$, $F(4, 102) = 5.64$, $p < .001$; total $R^2 = .53$]. Both omission errors, $B = .26$, $t = 2.42$, $p = .017$, and substitution errors, $B = .21$, $t = 2.61$, $p = .011$, remained unique predictors, along with the TICS total score, $B = -.22$, $t = -2.45$, $p = .016$, and the MAS list delayed recall measure, $B = -.24$, $t = -2.29$, $p = .024$. For the EPT, no additional significant variance was accounted for by the error measures when entered in the third block [$R^2 = .04$, $F(4, 116) = 1.87$, $p = .121$; total $R^2 = .31$] and there were no unique predictors in the full model, t 's < 1.9 , p 's $> .063$.

Discussion

Currently, there is limited understanding of the course of functional change that occurs between normal aging and dementia (Farias et al., 2006; Perneckzy et al., 2006; Tam et al.,

2007). To better characterize the nature of this change, the present study investigated the ability of cognitively healthy YAs and OAs, as well as individuals with MCI and dementia to perform eight scripted IADLs while under direct observation in a campus apartment. Task performances were coded for the following error types: inefficient actions, omissions, substitutions and irrelevant actions. We also sought to identify cognitive correlates of the task error types, and to determine which error measures best predicted performance on proxy measures of everyday functioning (i.e., informant-report and the EPT).

The overall accuracy score for the direct observation task (i.e., 8 IADLs) revealed that performance accuracy decreased with increased age and level of cognitive impairment. This indicates that our coding scheme was sensitive to subtle functional changes that occur as part of the normal aging process as well as those associated with cognitive impairment. Evaluation of task error types revealed that the cognitively healthy YA and OA groups did not differ in task omission errors, substitution errors, or irrelevant actions. Rather, the nature of the increased functional difficulties associated with healthy aging was primarily attributed to task inefficiencies. That is, in comparison to the YAs, the OAs engaged in more behaviors that affected the efficiency with which the eight activities were completed. Examples of observed inefficient actions included searching multiple locations for task items, having to correct mistakes or repeat a task step, making multiple trips to the same location, or asking for assistance. While the types of errors committed by the OAs in comparison to the YAs did not notably interfere with ability to correctly complete the tasks, the ease and efficiency with which the OAs completed the everyday tasks was compromised.

When compared to the OA control group, the performances of individuals with MCI were characterized by significantly more errors of omission. The MCI and OA groups did not differ in inefficient actions, substitution errors or irrelevant actions. Common omission errors included failure to retrieve objects needed for successful task completion and failure to complete task steps. These findings indicate that as cognitive abilities became compromised, omission errors became more prominent, resulting in interference with the accuracy of everyday task completion. Relative to the YAs, the errors of the MCI group were characterized by significantly more inefficient actions and omission errors as well as substitution errors (i.e., use of an alternate object or completion of an alternate task action), which can also interfere with accuracy of task execution.

The task performances of the dementia group were exemplified by significantly more inefficient actions, omission errors and substitution errors when compared to the YA and OA groups as well as the MCI group. In addition, the dementia group engaged in significantly more irrelevant task actions (i.e., off task actions unrelated to the task at hand) compared to the YA and OA groups. Overall, the errors made by the dementia group extensively compromised their ability to complete the everyday tasks accurately. In many cases, tasks were ended prematurely, alternate objects were used to complete tasks, irrelevant behaviors occurred, or alternate task actions were completed (e.g., dusted kitchen instead of living room). These findings are consistent with the diagnostic criteria for dementia which require that cognitive deficits result in impaired performance completing everyday activities of daily living.

In this study, the mean time that it took the OAs, MCI and dementia groups to complete the eight activities did not differ significantly. This contrasts with the findings of some prior studies conducted in laboratory settings which have found that individuals with MCI complete performance-based functional measures (e.g., Financial Capacity Instrument; Timed Instrumental Activities of Daily Living) more slowly than healthy OAs (Okonkwo et al., 2006; Wadley, Okonkwo, Crowe, & Ross-Meadows, 2008). In these studies, however, accuracy levels were generally comparable between the MCI and healthy OA groups. The current study findings most likely reflect the higher level of omission errors that were made by the MCI and dementia groups in comparison to the healthy OAs. More specifically, if a participant left out a task step necessary for accurate task completion (e.g., failing to water the plant in living room), this would have substantially lowered activity completion time.

Examination of the cognitive predictors of the varying error types provided information about cognitive domains contributing to specific everyday functional errors. Prior research suggests that, in addition to general cognitive abilities, executive functions and memory abilities are the two cognitive domains most consistently related to everyday functioning in the older adult population (e.g., Farias et al., 2006; Mariani et al., 2008; Rapp & Reischies, 2005). However, some studies have found that executive functioning, but not memory, is important in predicting everyday performance in an older adult population (e.g., Cahn-Weiner, Malloy, Boyle, Marran, & Salloway, 2000; Rapp & Reischies, 2005), whereas other studies have found the reverse (e.g., Jefferson et al., 2008; Tuokko, Morris, & Ebert, 2005). The current study findings suggest that executive and memory difficulties may lead to different types of errors being more prominently committed during everyday task completion.

The data revealed that omission errors were primarily related to the memory domain, while inefficient actions were more strongly linked with executive abilities. More specifically, after controlling for age and general cognitive functioning (i.e., TICS and SDMT oral), memory (but not executive functioning) accounted for additional variance in predicting omission errors. Furthermore, the memory measures continued to account for significant variance in omission errors even after controlling for executive abilities. Likewise, executive functioning (but not memory) played an important role in predicting inefficient actions. These findings fit well with the pattern of error difficulties observed across the populations. That is, the increase in inefficient actions observed in healthy OAs compared to YAs, is consistent with the well recognized finding that executive abilities are one of the more commonly affected cognitive domains associated with age-related cognitive decline (e.g., Allain et al., 2005; Zelazo, Craik, & Booth, 2004). Furthermore, compared to the cognitively healthy older and younger adults, the higher frequency of omission errors committed by the MCI group is consistent with the high proportion of MCI participants with memory impairment (i.e., amnesic MCI) in the current sample. In addition, neither memory nor executive functioning accounted for significant variance in substitution errors after accounting for age and general cognitive functioning. However, consistent with the finding that substitution errors occurred more readily as cognitive functioning became increasingly compromised, the TICS total score uniquely predicted task substitution errors.

These findings are consistent with recent studies using the Naturalistic Action Test (NAT; Schwartz et al., 2003), including research investigating cognitive correlates and brain structures with NAT performances in dementia populations (Bailey et al., 2013; Giovannetti et al., 2008b). More specifically, omission errors have been associated with cognitive correlates of episodic memory, as well as smaller volume in the hippocampus and medial temporal lobe in dementia patients (Bailey et al., 2013; Giovannetti et al., 2008b; Seidel et al., 2013). Commission errors, which represent inaccuracies in completing task steps, were predicted by executive dysfunction and found to be associated with decreased volume in the deep white matter and the dorsolateral prefrontal cortex of dementia patients (Bailey et al., 2013; Giovannetti et al., 2008b; Seidel et al., 2013). In contrast, a recent study with community dwelling OA and MCI participants revealed that neither NAT omission nor commission errors were predicted by memory or executive functioning measures (Seligman et al., 2014). However, the memory measure was found to predict the combined omission and commission errors after controlling for age and general cognitive status. It is important to point out that the definition of commission errors for the NAT includes both task inefficiencies and substitution errors. The present findings suggest that it may be essential to separate examples of inefficient actions from more diagnostically substantive substitution errors. We found that substitutions errors were related to general cognitive status and became more pronounced as cognitive impairment increased. Future research is needed to better understand possible cognitive contributors to substitution errors, such as impairment in semantic knowledge or confusion when retrieving (or encoding) task information.

Our data also suggest that irrelevant task actions warrant a separate error type and are most notable in individuals with dementia. This is consistent with recent work with the NAT, which now routinely characterizes action addition errors or off-task commissions (i.e., behaviors outside task parameters) as a separate category rather than including them in the category of general commission errors (e.g., Bailey et al., 2013; Seidel et al., 2013). In dementia patients, action additions have been linked with both white matter and gray matter structures and with the anterior cingulate cortex, further supporting the supposition that action additions represent a separate clinical aspect of error completion (Bailey et al., 2013; Seidel et al., 2013).

The present study also showed that, along with general cognitive status (i.e., TICS), omission and substitution errors uniquely predicted everyday functional status as measured by informant report. Furthermore, when memory and executive abilities were also held constant, these error type measures continued to account for additional variance in informant report, with omissions, substitutions, TICS and the MAS list delayed recall measures as unique predictors. Consistent with the finding that omission errors best distinguished the MCI and OA groups, and that substitution errors were predicted by general cognitive impairment, informants may be most cognizant of changes in everyday task performances when they lead to inaccuracies in task completion. For the performance-based EPT measure, omission errors uniquely predicted EPT performance when age and general cognitive status (i.e., TICS and SDMT oral) were controlled for. However, when the memory and executive measures were entered in the second block, the error measures failed to account for additional variance and there were no unique predictors. In this study, deficits captured by direct observation and the coding of more nuanced everyday errors showed a stronger

relation with an informant-report proxy measure of everyday functioning rather than a performance-based everyday problem-solving measure.

Taken together the different profiles of IADL errors among the OA, MCI, and dementia groups also have clinical implications for cognitive rehabilitation. The OA controls generally performed the tasks accurately but with less efficiency, suggesting that strategies targeting planning or prospective memory (e.g., cues to help with timing) may prove beneficial. The link between episodic memory and omission errors, coupled with the increase in omission errors in individuals with MCI, suggests that external aids that support memory (e.g., notebooks, calendars, reminder systems) and other cognitive rehabilitation therapies that target memory specifically may be most effective in maintaining everyday functional independence in individuals with MCI. As the incidence and nature of everyday errors becomes more severe in individuals with dementia, assistive technologies (e.g., picture based phones, object finders, electronic calendars, automatic stove shut-off products) that can help support functional independence and reduce caregiver burden will become more important. Prompting technologies designed to promote independent living in individuals with significant cognitive impairment are currently being explored (e.g., Czarnuch & Mihailidis, 2011; Schmitter-Edgecombe, Seelye, & Cook, 2013; Seelye, Schmitter-Edgecombe, Cook, & Crandall, 2013).

The generalizability of our findings may be limited by the fact that our older adult sample was predominantly Caucasian, highly educated, and reported low rates of depressive symptomology. In addition, our MCI group was predominantly comprised of participants with amnesic MCI, and future studies with larger sample sizes should more closely investigate whether the types of errors committed by amnesic and non-amnesic MCI participants differ. In addition, the small sample, unequal group sample sizes, and low base rates for some the errors types (i.e., irrelevant actions) may have affected power for some of our findings. Results of the regression analyses may be limited by the neuropsychological measures used to represent the cognitive constructs. In addition, while the study participants were generally in good physical health, future studies should better assess for non-cognitive physical limitations that might limit everyday functioning (e.g., mobility issues). Furthermore, although participants completed common everyday tasks, errors performing some of the tasks could represent lack of experience with the task (e.g., DVD task) rather than cognitive difficulties. To better address this potential confound and further understanding of the contribution of prior task experience on IADL performance, future studies should assess the impact of familiarity and experience on IADLs being completed in direct observation tasks. It should also be acknowledged that the apartment in which the eight IADLs were completed was not the home of the participant, and therefore some inefficiency may reflect adjustment to a new environment. Future studies should also consider evaluating adaptability and problem-solving within a new environment as a component of everyday functioning. Another limitation includes the presence of raters during the direct observation task; although these raters were out of sight during task completion, knowing that the individual is being evaluated may have influenced the accuracy of participant performance. In addition, future studies that make use of technologies (e.g., smart environments) that can unobtrusively and continuously monitor the everyday task performances of participants in their own homes will enhance our ability to

detect and predict functional change. Such studies are currently under way in our laboratory (Schmitter-Edgecombe et al., 2013).

In summary, we found that inefficient actions, which were most strongly linked to executive abilities and led to generally accurate but less efficient task performances, best characterized the errors committed by the cognitively-intact OA control group. Relative to the OA group, the MCI group committed significantly more omission errors, which led to task inaccuracies and were most strongly linked to memory abilities. Both inefficient actions and omission errors, along with substitution errors and irrelevant actions, were significantly more prominent in individuals with dementia and appreciably affected task performances. Taken together, the present data study suggests that in the progression from healthy aging to MCI, everyday task difficulties may evolve from task inefficiencies to task omission errors, leading to inaccuracies in task completion that are recognized by knowledgeable informants. Continued decline in cognitive functioning then leads to more substantial difficulties across all error types, compromising independent and accurate completion of everyday tasks, which is diagnostic of dementia.

Acknowledgments

This study was supported, in part, by grants from the Life Science Discovery Fund of Washington State and NIBIB (Grant #R01 EB009675). No conflicts of interest exist. We thank Jennifer Walker for her assistance in coordinating data collection. We also thank members of the WSU Cognitive Aging and Dementia laboratory for their help in collecting and scoring the data.

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Figure 1. Mean Error Types on the Direct Observation (8 IADLs) Task Displayed by Group

Table 1
Demographic Data and Mean Summary Data for Younger Adult, Healthy Older Adult, Mild Cognitive Impairment and Dementia Groups

Variable or Test	Group									
	YA (n = 53)		OA (n = 88)		MCI (n = 55)		Dementia (n = 18)			
	M	SD	M	SD	M	SD	M	SD		
Demographics										
Age	22.20	3.58	72.83 ^a	8.68	71.40 ^a	8.61	74.94 ^a	6.85		
Education (years)	14.95	1.69	15.79	2.71	15.25	3.20	16.27	2.78		
Gender % female	57%		68%		52%		28%			
GDS	---	---	1.62	1.82	2.86 ^b	2.65	2.80	3.19		
Global cognitive status										
TICS total score	---	---	34.24	2.55	32.58	3.10	24.39 ^{bc}	5.09		
Processing Speed										
SDMT - Oral total	74.10	14.13	54.23 ^a	11.03	42.18 ^{ab}	11.05	24.92 ^{abc}	11.67		
SDMT - Written total	65.07	10.93	47.41 ^a	9.48	38.29 ^{ab}	9.90	23.42 ^{abc}	12.97		
Verbal Memory										
MAS List Learning	63.72	6.51	60.57	5.81	48.07 ^{ab}	10.70	31.17 ^{abc}	14.55		
MAS Delayed Recall	11.75	.44	11.26	1.06	8.02 ^{ab}	3.79	3.11 ^{abc}	3.95		
BVMT-R Learning	29.84	5.19	22.94 ^a	5.63	13.73 ^{ab}	5.19	6.89 ^{abc}	5.58		
BVMT-R Delayed Recall	11.41	.80	9.34 ^a	2.40	5.61 ^{ab}	2.18	2.41 ^{abc}	2.87		
Executive Skills										
D-KEFS Letter Fluency	42.16	11.88	42.63	11.47	33.44 ^{ab}	14.50	22.35 ^{abc}	11.01		
D-KEFS Design Fluency	33.84	8.65	26.41 ^a	6.95	21.11 ^{ab}	6.99	11.06 ^{abc}	6.23		

Notes: Unless otherwise indicated, mean scores are raw scores. Norm sources for the cognitive tests are in parentheses following the test. YA = younger adults; OA = older adult; MCI = mild cognitive impairment; GDS = Geriatric Depression Scale – Short Form (Sheikh & Yesavage, 1986); TICS = Telephone Interview for Cognitive Status (Brandt & Folstein, 2003); SDMT = Symbol Digit Modalities Test (Smith, 1991); MAS = Memory Assessment Scale (Williams, 1991); BVMT-R = Brief Visuospatial Memory Test - Revised (Benedict et al., 1996); D-KEFS = Delis-Kaplan Executive Function System (Delis, Kaplan, & Kramer, 2001).

^aDiffers from YA;

^b Differs from OA;
^c Differs from MCI;
^d n = 32;
^e n = 54;
^f n = 87;
^g n = 17;
^h n = 12;

Table 2
Coding Schema for Error Types and Overall Accuracy Score for Direct Observation Task
(8 IADLs)

Occurrences of the following errors were coded for each of the eight activities. An overall score was derived for each activity, and these eight scores were summed for a direct observation total accuracy score. See Schmitter-Edgecombe et al., 2011.
<i>Inefficient Action:</i> Coded when an action that slows down or compromises the efficiency of task completion is performed (e.g., making multiple trips to the dining room table, opening and closing extraneous cupboards and drawers unnecessary for task completion).
<i>Omission Error:</i> Coded when a step or subtask necessary for accurate task completion is not performed (i.e., critical omission; e.g., failure to retrieve broom for sweeping and dusting task); or when a step or subtask is not performed but the activity is still completed accurately (i.e., non-critical omission; e.g., failure to turn off the television for DVD task).
<i>Substitution Error:</i> Coded when an alternate object, or a correct object but an incorrect gesture, is used and disrupts accurate completion of the activity (i.e., critical substitution; e.g., dusting the kitchen instead of the living room); or when an alternate object, or a correct object but an incorrect gesture, is used but the activity is still completed accurately (i.e., non-critical substitution; e.g., uses container other than watering can to water plants).
<i>Irrelevant Action:</i> Coded when an action that is unrelated to the activity, and completely unnecessary for activity completion, is performed (e.g., opens the refrigerator when completing the sweeping and dusting task).
<p><i>Subtask Activity Score</i> (derived for each of the 8 tasks)</p> <p>1 = task completed without any errors</p> <p>2 = task completed but with no more than 2 total of the following errors: non-critical omissions, non-critical substitutions, irrelevant actions, inefficient actions</p> <p>3 = task completed but with more than 2 total of the following errors: non-critical omissions, non-critical substitutions, irrelevant actions, inefficient actions</p> <p>4 = task incomplete, coded when a <u>critical</u> omission or substitution occurs; more than 50% of the task must be completed</p> <p>5 = task incomplete, coded when a <u>critical</u> omission or substitution occurs; less than 50% of the task completed</p> <p><i>Total Accuracy Score (Direct Observation Score):</i> Sum of the eight activity scores (range 8–40).</p>

Table 3
Direct Observation Measures for Younger Adult (YA), Older Adult (OA), Mild Cognitive Impairment (MCI) and Dementia Groups.

Variable or Test	Group							
	YA (n = 53)		OA (n = 88)		MCI (n = 55)		Dementia (n = 18)	
	M	SD	M	SD	M	SD	M	SD
Direct Observation Measures								
Total Time	28.78	4.57	35.17 ^a	6.24	36.09 ^a	5.96	36.32 ^a	11.61
Total Accuracy Score	12.59	2.68	14.86 ^a	3.42	18.20 ^{ab}	6.40	27.65 ^{abc}	7.21

Note: Scheffe post hoc tests significant difference from

- (a) YA,
- (b) OA,
- (c) or MCI

Table 4
Correlation Matrix for Error Types Collapsed Across the Older Adult Groups with Age
and General Cognitive Status Partialled Out ($n = 161$)

	Inefficient Actions	Omissions	Substitutions	Irrelevant Actions
Inefficient Actions	1.0	.18	.02	.22*
Omissions		1.0	.33**	.04
Substitutions			1.0	.05
Irrelevant Actions				1.0

*
 $p < .01$;

**
 $p < .005$

Table 5
Correlations between the Error Type Variables and Demographic and Neuropsychological Data for the Combined Older Adult Group

Variables	Error Type			
	Inefficient Actions	Omissions	Substitutions	Irrelevant Actions
Age	.20 [*]	.31 ^{**}	.11	.11
Education	.04	.02	-.05	.11
Gender	.08	.16	.15	.15
Geriatric Depression Scale	-.00	.07	.07	.07
TICS	-.43 ^{**}	-.58 ^{**}	-.44 ^{**}	-.30 ^{**}
SDMT - Oral	-.35 ^{**}	-.63 ^{**}	-.38 ^{**}	-.14
MAS Delayed List recall	-.36 ^{**}	-.64 ^{**}	-.39 ^{**}	-.17 [*]
BVMT-R delayed recall	-.35 ^{**}	-.61 ^{**}	-.39 ^{**}	-.23 [*]
D-KEFS Letter Fluency	-.24 [*]	-.36 ^{**}	-.24 ^{**}	-.22 [*]
D-KEFS Design Fluency	-.42 ^{**}	-.51 ^{**}	-.41 ^{**}	-.29 ^{**}

Notes: Total correct raw score was used for all neuropsychological measures. TICS = Telephone Interview for Cognitive Status; SDMT = Symbol Digit Modalities Test; MAS = Memory Assessment Scale; BVMT-R = Brief Visuospatial Memory Test - Revised; D-KEFS = Delis-Kaplan Executive Function System.

^{*}
 $p < .01$;

^{**}
 $p < .001$

Table 6
Summary of Hierarchical Regression Analyses for Variables Predicting the Everyday Functional Status Measures

Variables	Error Types			
	Inefficient Actions	Omissions	Substitutions	Irrelevant Actions
Model 1				
Age	.09	.09	-.08	.09
TICS	-.27**	-.23**	-.29**	-.04
SDMT - Oral	-.18	-.45**	-.23*	-.10
R ²	.19**	.41**	.18**	.03
F for R ²	11.10	32.68	10.5	1.51
Model 2 (memory)				
Age	.10	.10	-.08	-.08
TICS	-.24*	-.12	-.24*	-.05
SDMT - Oral	-.14	-.27**	-.12	-.10
MAS List Delayed Recall	-.13	-.28**	-.10	.06
BVMT-R Delayed Recall	.02	-.15	-.14	-.04
R ² change	.01	.09**	.03	.00
F for R ² change	.992	13.34	2.49	.16
Model 2 (executive)				
Age	.05	.09	-.12	.07
TICS	-.24*	-.23**	-.27**	.00
SDMT - Oral	-.08	-.45**	-.16	.01
D-KEFS Letter Fluency	.04	.03	.08	-.08
D-KEFS Design Fluency	-.24*	-.01	-.20	-.16
R ² change	.03	.00	.02	.02
F for R ² change	2.86	.06	2.05	1.67
Model 3				
Age	.06	.11	-.11	.06
TICS	-.21*	-.13	-.23*	-.01
SDMT - Oral	-.07	-.30**	-.09	-.01
MAS List Delayed Recall	-.15	-.28**	-.11	.07
BVMT-R Delayed Recall	.09	-.16	-.09	-.02
D-KEFS Letter Fluency	.06	.02	.07	-.09
D-KEFS Design Fluency	-.25*	.05	-.17	-.16

Variables	Error Types			
	Inefficient Actions	Omissions	Substitutions	Irrelevant Actions
Final R ²	.23	.50	.22	.05

Notes: Standardized Coefficients Beta reported in Table. TICS = Telephone Interview for Cognitive Status; SDMT = Symbol Digit Modalities Test; MAS = Memory Assessment Scale; BVMT-R = Brief Visuospatial Memory Test - Revised; D-KEFS = Delis-Kaplan Executive Function System.

*
 $p < .05$;

**
 $p < .005$