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Executive Function Subcomponents and their Relations to Everyday Functioning in Healthy Older Adults

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Abstract

Everyday functioning and its executive functioning cognitive correlates (i.e., switching, inhibition, and updating) were investigated in healthy older adults (HOAs) using multiple methods of functional status. In addition to whether computerized experimental tasks would better dissociate these subcomponents than neuropsychological measures of executive functioning, we were also interested in the contributions of both experimental and neuropsychological measures of executive function subcomponents to functional abilities. Seventy HOAs (45 young-old and 25 old-old) and 70 younger adults completed executive function and neuropsychological tests. In addition to self- and informant questionnaires of functional abilities, HOAs completed two performance-based measures. An aging effect was found on all executive function measures. Old-old older adults and their informants did not report more functional difficulties but demonstrated more difficulties on performance-based measures relative to young-old participants. For the HOAs, after controlling for age and education, the neuropsychological measures of executive functioning, but not experimental measures, explained a significant amount of variance in the informant-report and both performance-based measures. Updating measures differentially predicted performance-based measures, while switching was important for questionnaire and performance-based measures. The contribution of executive functioning to functional status when measured with experimental measures specifically designed to isolate the executive subcomponent was not as strong as hypothesized. Further research examining the value of isolating executive function subcomponents in neuropsychological assessment and the prediction of functional abilities in older adults is warranted.

Keywords

Updating; Switching; Inhibition; Aging; Instrumental Activities of Daily Living

The ability to function independently in the community, including managing finances, taking medications, and preparing meals is determined by multiple social, physical, emotional, and cognitive factors. Among these, cognition has been shown to be the strongest predictor of everyday functioning within the aging population (e.g., Cahn-Weiner, Malloy, Boyle, Marran, & Salloway, 2000; Farias et al., 2009). Numerous cognitive factors have been found

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to contribute to functional decline in the older adult population, including global cognitive status, memory, processing speed, visuoperceptual abilities, and executive functioning. Although the extent to which particular cognitive abilities are most predictive of functional status remains unclear, executive functioning has emerged as a consistent predictor of everyday functioning in healthy older adults (HOAs).

Executive functions are broadly defined as a collection of correlated but highly separable higher order supervisory control processes involved in the flexible production and regulation of complex goal-directed problem-solving thoughts and actions, particularly in non-routine situations. Intact executive functions bolster a multitude of everyday, “real world” functions including planning and sequencing complex task goals, initiating goal-directed behavior, multitasking, sustaining attention despite interference or distraction, and terminating behavior. The frontal hypothesis of aging postulates that since the frontal areas disproportionately deteriorate earlier and more severely than other cerebral areas with age, the cognitive functions dependent on the integrity of the prefrontal regions will be among the first to deteriorate (e.g., Daigneault, Braun, & Whitaker, 1992; Dempster, 1992; West, 1996). Given that “complex daily tasks have the hallmark components of executive function” (Willis et al., 1998, p. 570), it is clear that the well-established age-related declines in executive functioning could have negative consequences on functional outcomes.

Although executive functioning as a neuropsychological construct has long been considered a unitary, general purpose higher order ability, often measured with a single, complex “frontal lobe task” (e.g., WCST; Friedman et al., 2008), it may be more accurately characterized as a collection of multiple related but separable or dissociable executive processes, a pattern referred to as the “unity and diversity” of executive functions (Teuber, 1972). This multicomponent or “fractionated” view implies that different executive subcomponents are partially independent, with low correlations (diversity), yet sufficiently related to represent a unique executive functioning construct (unity) (Friedman, Miyake, Robinson, & Hewitt, 2011).

There have been many proposed models that have explored the underlying dimensions of various batteries of supposed executive functioning tasks to determine the existence of differentiated components, with several being identified (see also Packwood, Hodgetts, & Tremblay, 2011). For example, Miyake et al.'s (2000) influential model used latent variable analysis in a sample of younger adults using nine experimental executive tasks to specify the extent of the relationship among three commonly identified subcomponents of executive functioning: task shifting, inhibition, and updating. Task shifting, also referred to as “attention switching” or “task switching,” involves flexibly switching attention and cognitive control back and forth between multiple relevant tasks or subtasks, operations, or mental sets while overcoming proactive interference or negative priming due to having previously performed a different operation on the same type of stimuli (Miyake et al., 2000; Monsell, 2003). Inhibition concerns the ability to deliberately suppress and override dominant, automatic, or prepotent conflicting responses while ignoring extraneous information. Lastly, the updating component refers to monitoring and evaluating incoming information for task-relevance and then appropriately revising the existing contents in working memory by

modifying older, no longer relevant information with more recent and relevant information (Miyake et al., 2000; Morris & Jones, 1990).

Results from Miyake et al.'s study provided support for the non-unitary, multifaceted nature of executive functioning. These authors found that the three subcomponents were moderately correlated, but clearly distinguishable, and differentially contributed to performance on various complex executive functioning tasks (e.g., WCST). More recent studies, including neuroimaging studies (e.g., Collette & Van der Linden, 2002), have also found separable executive components, most frequently a three-factor model with similar components as Miyake et al. (2000), with other populations including older adults, children, and clinical populations (e.g., Androver-Roig, Sesé, Barceló, & Palmer, 2012; de Frias, Dixon, & Strauss, 2009; Hedden & Yoon, 2006; Hull, Martin, Beier, Lane, & Hamilton, 2008; Novakovic-Agopian et al., 2014; Vaughan & Giovannello, 2010). Although other executive functions have been examined, including dual tasking, planning, and access to long-term memory (Fisk & Sharp, 2004; Ginani et al., 2011), task switching, inhibition, and updating have most frequently been identified as important subprocesses in the executive function research. However, caution is needed when choosing the tasks to assess these three subcomponents as most neuropsychological tests may be less ideal than experimental tasks for isolating individual executive subcomponents. This is because the scores derived from most neuropsychological tests are dependent upon multiple cognitive processes for completion (e.g., task switching, speeded processing, visuoperceptual abilities) while computerized experimental tasks can be “matched as far as possible in terms of lower-level processes” (Dafters, 2006, p. 181) so that the subcomponent of interest (e.g., task switching) can be independently measured.

Previous studies have shown a clear relationship between executive functioning and functional abilities (e.g., McAlister & Schmitter-Edgecombe, 2013; Schmitter-Edgecombe & Parsey, 2014). However, most studies have not taken a “fractionated” approach to studying the relationship between executive functions and functional abilities, and instead, have relied on more broad conceptualizations and generally assessed only one component of executive functioning. Therefore, the specific executive functioning subcomponents most involved in functional abilities remains unclear.

Studies that have used neuropsychological measures to investigate the relationship between functional abilities and subcomponents of executive functioning have yielded mixed results. For example, with cognitively healthy older adults, Jefferson, Paul, Ozonoff, and Cohen (2006) found that inhibition (as measured by DKEFS Color-Word Interference Test) was most strongly related to IADL impairment, while Bell-McGinty and colleagues (Bell-McKinty, Podell, Franzen, Baird, & Williams, 2002) identified task-switching (as measured by Trail Making Test-Part B), and Lewis and Miller (2007) planning (as measured by Tower of London and Porteus Maze Test), as most predictive. These varying conclusions may be resultant of the different executive functioning measures that were used and the fact that these measures may also be heavily reliant on other cognitive processes (e.g., speeded processing). Studies have also found that the relationship between executive functioning and functional status may vary depending on whether performance- or questionnaire-based assessments are utilized (Gold, 2012). For example, Cahn-Weiner, Boyle, and Malloy (2002)

found that task switching significantly correlated with both performance-based (i.e., behavior simulation) and informant-rated measures of IADLs, while verbal fluency performance was strongly associated with informant-report only. These findings suggest that executive subprocesses may be differentially related to IADLs depending on assessment measure.

Several recent studies have utilized computerized experimental tasks that allow for more specific isolation of executive function subcomponents to explore the relationship between executive functions and IADLs. For example, Vaughan and Giovanello (2010) used computerized experimental measures of task-switching, inhibition, and updating to explore the relationship between executive subprocesses and functional abilities in cognitively healthy older adults. They showed that task switching had a strong and significant relationship with performance-based (i.e., behavior simulation), but not self-report, IADLs. Also using computerized experimental measures of executive subcomponents from Miyake et al.'s (2000) model with community-dwelling older adults, Han (2010) found that a composite measure of inhibition was the best predictor of a performance-based measure (i.e., behavior simulation) of IADLs.

To our knowledge, few studies have examined the relationship between executive function subprocesses and multiple measures of functional ability in healthy older adults, and none have included informant-report. The primary aim of this study was to identify which executive function subcomponents, as measured by both computerized experimental tasks and neuropsychological measures, were most related to everyday activity completion in healthy older adults across several methods for assessing functional status (i.e., self- and informant-report, behavior simulation and everyday problem solving). More specifically, we sought to evaluate whether the executive function subcomponents identified as important in Miyake et al.'s (2000) influential model (i.e., task switching, inhibition, and updating) would account for significant variance in functional status. In addition, despite suggestions that older adults aged 75+ are at greater risk for limitation in functional status (Lafortune & Balestat, 2007), there is limited understanding of the course of change in functional abilities with advanced age. Therefore, we were interested in comparing young-old (age 60-74) and old-old (age 75+) older adult groups' performances on the multiple measures of functional abilities as well as executive functioning.

We expected that the old-old would perform more poorly than the young-old older adults who would perform more poorly than the younger adults on the measures of functional status as well as executive functioning. Based on prior literature (e.g., Han, 2010; Vaughan & Giovanello, 2010), after controlling for demographic variables, it was hypothesized that the executive functioning subcomponents would explain a significant amount of the variance in functional status as measured by both questionnaire and performance-based measures. We also expected that the computerized experimental tasks would provide more independent and dissociable measurement of the executive functioning subcomponents than the neuropsychological measures of executive functioning. With few studies having explored the role of updating in functional abilities, we were especially interested in the contribution of updating. Given the importance of regularly updating information when completing laboratory-based task, it was hypothesized that updating would account for significant

variance in functional status as documented by performance-based tests after controlling for other predictors.

Method

Participants

Participants were 70 community-dwelling, cognitively healthy older adults (HOAs), aged 50 and above, and 70 undergraduate students (younger adults, YAs) (Table 1). To assess whether functional and executive function difficulties were more common in individuals age 75+ rather than also being apparent in the young-old, we also differentiated the HOAs into two age groups, young-old ($N = 44$; $M = 67.84$, $SD = 3.68$; range 61-74; 32F, 12M) and old-old ($N = 25$; $M = 78.84$, $SD = 3.33$; range 75-87, 13F, 12M).

Older adult participants were recruited through advertisements, community health and wellness fairs, physician and local agency referrals, and from past studies in our laboratory. Younger adult participants were recruited through the psychology participant pool and received course credit. Initial screening for older adult participants was conducted over the phone and included: (a) a medical interview to rule out exclusion criteria, and (b) the Telephone Interview for Cognitive Status (TICS) to exclude participants who scored below 27 (equivalent of an MMSE of 24) on a measure of global cognitive functioning (Brandt & Folstein, 2003). Exclusionary criteria included history of brain surgery, cerebrovascular accident, or head trauma with permanent brain lesion; current or recent (i.e., within the past year) psychoactive substance abuse; a known medical, neurological, or psychiatric cause of cognitive dysfunction; and self- or knowledgeable informant-report of significant memory complaints or changes in cognitive or functional ability.

Participants meeting initial screening criteria completed laboratory-based standardized and experimental neuropsychological tests across two testing sessions. The first session lasted approximately 3 hours and the second session 2 hours. As compensation, older adult participants were given pre-paid parking passes, travel compensation, a report documenting their performance on the neuropsychological tests, and \$20 for completing the second session. Older adult participants did not meet criteria for dementia (American Psychiatric Association, 2000) or Mild Cognitive Impairment (MCI) as outline by the National Institute on Aging-Alzheimer's Association workgroup (Albert et al., 2011).

Measures

The executive function measures represent three commonly identified subcomponents of executive functioning: shifting, inhibition, and updating. Both a computerized experimental measure that allowed for better isolation of the individual executive subcomponent and a neuropsychological measure were chosen for each subcomponent. Construct validity and other psychometric properties for the computerized experimental measures can be found in Miyake et al. (2000). In addition, three measures representing cognitive constructs not expected to have a significant relationship with functional abilities in healthy older adults (i.e., language, memory, visuospatial abilities) were also selected as predictors. Outcome measures included both questionnaire and performance-based measures of functional status.

Computerized experimental executive function measures

Number-Letter Task: Shifting (Miyake et al., 2000; Rogers & Monsell, 1995): A number-letter pair (e.g., 7G) was presented in one of four quadrants of a square on a computer screen. Participants were asked to indicate as quickly and accurately as possible with a button press whether the number was odd or even (2, 4, 6, and 8 for even; 3, 5, 7, and 9 for odd) when the number-letter pair was presented in either of the top two quadrants and whether the letter was a consonant or vowel (G, K, M, and R for consonant; A, E, I and U for vowel) when the number-letter pair was presented in either of the bottom two quadrants. Number-letter pairs were presented only in the top two quadrants in the first block of 32 trials, only in the bottom two quadrants in the second block of 32 trials, and randomly in all four quadrants in a clockwise rotation in the third block of 128 trials. There were 10 practice items in the first two blocks and 24 in the third block. Trials in the first two blocks did not require switching, whereas half of the trials in the third block required switching between two types of categorization operations at predictable positions. Stimuli were presented until a response was made with a 150 ms inter-trial interval. Shift cost was the difference between the average reaction times of trials in the third block that required a mental shift (trials from the upper left and lower right quadrants) and the average reaction times of trials from the first two blocks in which no shift was necessary, divided by the average reaction time of trials in the first half.

Antisaccade task: Inhibition (Miyake et al., 2000; Roberts, Hager, & Heron, 1994): In each trial, a fixation point was presented in the center of the screen for a variable duration (one of nine times randomly between 1500 and 3500 ms in 250 ms intervals). A visual cue (a 1/8-in. black square) was displayed for 225 ms on either the left or right side of the screen followed by a target stimulus (7/16-in. arrow inside an open square) for 175 ms on the opposite side of the screen before it was masked by gray cross-hatching. The mask remained on the screen until the participant indicated the direction of the arrow (left, up, or right) with a button press response. Cues and targets were presented 3.4-in. from the fixation point. Since the targets appeared only briefly, participants were required to inhibit the reflexive response of looking at the cues as this would make it more difficult to correctly identify the direction of the arrow. After 22 practice trials, participants completed three blocks of 30 trials for a total of 90 trials. The number of trials answered correctly served as the dependent measure of inhibition.

Keep Track Task: Updating (Miyake et al., 2000; Yntema, 1963): In each trial, participants were first shown target categories at the bottom of a computer screen. Target categories remained on the screen while fifteen words, two or three exemplars from each of six categories (animals, colors, sports, furniture, instruments, fruits), were presented serially and in random order for 2000ms apiece. Participants were asked to recall the last word presented in each of the target categories while the examiner wrote down their responses and encouraged them to guess if an insufficient number of words were recalled. Thus, participants had to closely monitor the words presented and update their working memory representations for the appropriate categories when the presented word was a member of the target categories. All six categories and exemplars were presented to participants before the task to ensure they knew to which category each word belonged. They practiced on a sample

and two practice trials with two target categories. Participants then performed three trials for each of two, three, and four categories, recalling a total of 27 words. The number of words correctly recalled was used as a measure of updating.

Neuropsychological executive function measures

Trail Making Test: Shifting (Reitan & Wolfson, 1985): Participants were asked to rapidly alternate between connecting numbers (Trails A), and numbers and letters (Trails B). The time the individual took to complete Trails B minus Trails A was used as a measure of shifting (e.g., Vazzana et al., 2010).

Hayling Sentence Completion test: Inhibition (Burgess & Shallice, 1997): Participants were read two sets of 15 sentences in which the final word was missing. In the first half, participants were asked to complete the sentences with a word related to the sentence as quickly as possible, while in the second half, participants were asked to complete the sentences with a word unrelated to the sentence as quickly as possible. The total time to complete sentences in the second half minus the total time to complete sentences in the first half was used as a measure of inhibition.

Reading Span task: Updating (Daneman & Carpenter, 1980): Participants were presented with 60 sentences, ranging from 14 to 22 words in length, on a 5.5 × 8.5-in. white cardstock booklet, one at a time, and asked to read each sentence out loud. Immediately after a sentence was read, the card was turned, and participants were asked to read the next sentence. Following the last sentence in a set, a card signaled participants to recall the last word of each sentence of the set in the order in which they occurred. The task was discontinued if participants failed to recall the last word of each sentence in all three sets of a particular block, regardless of if they were in the correct order. Participants first practiced on a two-sentence set. Following this, the test blocks began with three two-sentence sets and progressed to a maximum of three six-sentence sets. The total number of words correctly recalled was used as a measure of updating.

Neuropsychological measures representing other cognitive domains

Memory Assessment Scale: Prose Memory subtest (MAS; Williams, 1991): After hearing a three-sentence story, participants were asked nine questions about the story, both immediately and after a long delay. Retrospective memory was represented by the total number of correctly answered questions at the long delay.

Facial Recognition Test (Benton, Sivan, Hamsher, Varney, & Spreen, 1994): Participants were asked to select faces from black and white photographs that matched the original target face. Total number correct was used as a measure of visuospatial abilities.

Boston Naming Test (BNT; Ivnik, Malec, Smith, Tangalos, & Petersen, 1996): Participants were asked to name line-drawing of objects. The BNT was administered and scored using the standardized procedures outlined by Kaplan et al. (1983). Total naming score was used as a measure of language abilities.

Functional status measures

Instrumental Activities of Daily Living: Compensation Scale (IADL-C; Schmitter-Edgecombe, Parsey, & Lamb, 2014): Participants and their knowledgeable informants completed the IADL-C, a 27-item questionnaire of everyday functioning. Each item was rated using an 8-point Likert scale, ranging from 1 (*independent, as well as ever, no aid*) to 8 (*not able to complete activity anymore*). Ratings included four levels of independent functioning and three levels of needing increasing amounts of assistance. Categories for indicating that the participant “*does not need to complete the activity*” or that there is “*no basis for judgment*” (informant version only) were also presented. A log-transformed total score was created by summing the items with higher scores indicating poorer functional abilities.

UCSD Performance-Based Skills Assessment-Brief Version (UPSA-Brief; Mausbach, B. T., Harvey, P. D., Goldman, S. R., Jeste, D. V., & Patterson, T. L., 20007; Patterson, T.L., Goldman, S., McKibbin, C. L., Hughs, T., & Jeste, D. V., 2001): Participants were asked to role-play tasks in two areas of functioning: communication (e.g., reschedule an appointment) and finances (e.g., write a check). The percentage of items correct on each subscale was multiplied by a weight of 50, and the two subscale scores were summed for a total score.

The Everyday Problems Test (EPT, Willis & Marsiske, 1993): Participants were presented with 14 everyday stimuli (e.g., medication labels, transportation schedules), representing seven IADL domains (medications, telephone, transportation, household, finance, shopping, and meal preparation) and asked to answer two paper and pencil, open-ended questions about each stimulus. The total number of correct items out of 28 was used as the dependent measure.

Results

Analyses

One-way ANOVAs and *t*-tests and were used to compare group performances (i.e., younger adults, young-old and old-old older adults) on demographic variables, everyday functioning, neuropsychological, and executive functioning measures. When group differences were found, Tukey's HSD post hoc comparisons were used. Pearson correlations examined for relationships between the neuropsychological and computerized experimental measures of the same executive functioning subcomponent. Pearson correlations were also used to compare executive function and neuropsychological variables representing other cognitive domains (i.e., memory, language, and visuospatial abilities) to everyday functioning measures. Measures (i.e., IADL-C) not normally distributed were log-transformed. Hierarchical regression analyses were used to examine the relationship between both the experimental and neuropsychological measures of executive functioning subcomponent predictors (i.e., task shifting, inhibition, and updating) and functional status performances across all functional status measures for older adults. Young-old and old-old older adult groups were combined for the regression analyses, to increase variability and because the sample size for the old-old older adult group was small. Younger adults were excluded from

regression analyses as younger adults were not the primary focus of this study. Age and education were both entered into the first block of the regression. The three executive function subcomponents were then entered simultaneously in the next block for each of the functional status measures. Hierarchical regression analyses were also used to examine the relationship between neuropsychological measures (i.e., memory, language, and visuospatial abilities), and functional status performances.

Participant Characteristics

Table 1 shows the demographic data for the younger and older adult groups. Mean education was similar for the older adult groups ($p = .98$) and higher than the younger adults (p 's < .02). There was no significant difference in the gender distribution of the groups, $\chi^2(2) = 3.56$, $p = .17$.

Executive Function and Neuropsychological Predictors

Table 2 shows the means and standard deviations for the executive function and neuropsychological variables for the older and younger adult groups.

Computerized experimental executive function measures—One-way ANOVAs revealed significant differences between groups on all of the computerized experimental executive function measures, F 's > 12.77, p 's < .001. Tukey post hoc comparisons revealed that the older adults performed more poorly than the younger adults on all measures, p 's < .01, and that the old-old older adults performed more poorly than the young-old older adults on measures of inhibition ($p < .001$) and updating ($p < .001$) but not switching ($p = .53$).

Neuropsychological executive function measures—One-way ANOVAs revealed significant differences between groups on all of the neuropsychological executive function measures, F 's > 13.69, p 's < .001. Tukey post hoc comparisons revealed that the older adults performed more poorly than the younger adults on the inhibition (p 's < .001) and updating measures (p 's < .05). The old-old older adult group performed similarly to the young-old older adult group on the measure of inhibition ($p = .48$) but not updating ($p < .01$). Both the younger adults and young-old older adults performed similarly on a measure of switching ($p = .25$), and better than the old-old older adults (p 's < .01).

Neuropsychological measures representing other cognitive domains—One-way ANOVAs revealed significant differences between groups on measures of memory, $F = 5.46$, and language, $F = 16.98$, but not visuospatial abilities, $F = .33$. Consistent with the aging literature (e.g., Schmitter-Edgecombe, Vesneski, & Jones, 2000), in comparison to the younger adults, the older adults performed better on a measure of language (p 's < .001), and the performance of the young-old and old-old adults did not differ ($p = .31$). Both younger adults and young-old adults ($p = .11$), and younger and old-old ($p = .87$) performed similarly on a memory measure ($p = .11$), but young-old performed better than old-old adults ($p < .01$).

Functional Status Measures

Summary data for the functional status measures is found in Table 3. Younger adults were not administered the functional status measures, and therefore no age comparisons could be made. For the young-old and old-old older adult groups, no significant differences were noted for the IADL-C for either self-report, $t(61) = -.46$, $p = .65$, or informant report, $t(50) = -.34$, $p = .74$. However, there were significant differences between the age groups on both performance-based measures [EPT, $t(65) = 3.35$, $p < .01$; UPSA, $t(67) = 2.59$, $p < .05$] with the old-old older adult group performing more poorly than the young-old older adult group.

Intercorrelations between Executive Function and Neuropsychological Measures

Table 4 shows the intercorrelations amongst the executive functioning and neuropsychological measures for the HOAs. A more conservative significance value of $p < .01$ was used due to the large number of comparisons being made. There were no significant correlations amongst the three computerized experimental measures of executive functioning (r s between $-.30$ and $.27$), suggesting that these tasks were measuring relatively independent, dissociable aspects of executive functioning. In contrast, there were significant correlations among the three neuropsychological measures of executive function (see Table 4), suggesting some overlap in cognitive abilities being measured. Furthermore, the neuropsychological measure of switching (i.e., Trails B) significantly correlated with the computerized experimental measures of inhibition (i.e., Antisaccade; $r = -.36$) and updating (i.e., Keep Track Task; $r = -.43$) and approached significance with the experimental measure of switching (i.e., Number Letter Task; $r = .23$, $p = .06$). In addition, while the experimental and neuropsychological measures of inhibition did not significantly correlate ($r = -.15$, $p = .22$), there was a significant correlation between the updating measures ($r = .53$, $p < .001$). Only one executive function measure (i.e., Reading Span) significantly correlated with the neuropsychological measures outside of executive functioning (i.e., memory: $r = .36$; language: $r = .43$), suggesting relatively independent cognitive domain constructs.

Intercorrelations between Measures of Functional Status

Table 5 shows the intercorrelations amongst the four measures of functional status for the entire HOA group. The self- and informant-report IADL-C did not correlate with each other. No significant correlations were found between the self- or informant-report IADL-C and the two performance-based measures (i.e., EPT and UPSA). The two performance-based measures were significantly correlated, $r = .50$, $p < .001$.

Regression Analyses

Hierarchical regression analyses were conducted to investigate whether the computerized experimental executive, neuropsychological executive, or other neuropsychological measures could predict functional status for the HOAs. Total scores for the self- and informant-report IADL-C, UPSA, and EPT were used as the primary outcome measures of everyday functioning. Demographics (i.e., age and education) were entered in the first block, and then the three experimental measures of executive functioning subcomponents were entered simultaneously into the second block. This method was repeated with the neuropsychological measures of executive functioning and the other neuropsychological

measures (i.e., memory, language, and visuospatial abilities). The Variance Inflation Factors for each variable were less than 2.04 indicating little multicollinearity within the three sets of predictor variables. Table 6 shows correlations amongst the predictor and criterion variables. Table 7 displays the beta coefficients for all of the predictors entered into the regression analyses.

Computerized experimental executive function measures—Analysis of the regression models (see Table 7) revealed that the experimental executive functioning subcomponent measures did not account for significant variance above and beyond age and education ($R^2 < .10$) for either the self-report IADL-C [$F(3, 53) = 1.16, p = .33$], informant-report IADL-C [$F(3, 41) = .22, p = .88$], EPT [$F(3, 57) = 1.61, p = .20$], or UPSA [$F(3, 59) = 2.14, p = .11$]. Demographic variables accounted for a significant 11% of the variance in the UPSA total, $F(2, 62) = 3.71, p < .05$, and 32% of the variance in the EPT, $F(2, 60) = 14.17, p < .001$. When all five independent variables were included in the second stage of the regression model, the Number Letter Task (switching) approached significance as an important predictor for the UPSA ($t = -1.79, p = .08$), while age ($t = -2.26, p < .05$), education ($t = 3.61, p < .01$), and the Keep Track Task (updating) ($t = 2.16, p < .05$) were all significant predictors of EPT performance.

Neuropsychological executive function measures—The neuropsychological executive function measures did not account for significant variance above and beyond age and education for the self-report IADL-C [$F(3, 54) = .01, p = 1.00$]. In contrast, the neuropsychological executive function measures accounted for significant variance, above and beyond variance explained by age and education ($R^2 > .18$, see Table 7), for the informant-report IADL-C [$F(3, 43) = 4.07, p < .05$], UPSA [$F(3, 61) = 7.06, p < .001$], and EPT [$F(3, 59) = 7.91, p < .001$]. When all five independent variables were included in the regression model, Trails B (switching) emerged as a significant predictor for the informant-report IADL-C ($t = 3.27, p < .01$), and Trails B ($t = -3.83, p < .001$) and education ($t = 2.50, p < .05$) were significant predictors of EPT performance. For the UPSA, Reading Span (updating) was a significant predictor ($t = 3.31, p < .01$), while Trails B approached significance ($t = -1.99, p = .05$).¹

Neuropsychological measures representing other cognitive domains—The neuropsychological measures did not account for significant variance above and beyond age ($R^2 < .07$) for the self-report IADL-C [$F(3, 56) = .65, p = .58$], informant-report IADL-C [$F(3, 46) = .24, p = .87$], or UPSA [$F(3, 63) = 1.63, p = .19$]. When all five independent variables were included in the regression model, education was a significant predictor of the self-report IADL-C ($t = -2.08, p < .05$). For the EPT, the neuropsychological measures explained an additional 9% of the variance [$F(3, 61) = 3.27, p < .05$], above and beyond the 35% of variance explained by age and education; however, age ($t = -2.22, p < .05$) and

¹To check that we had adequately controlled for the possible influence of processing speed in the methods used to compute the executive functioning subcomponents, we reran the regression analyses controlling for both demographics and processing speed (measured by Trails A). For all functional status measures, there was no change in the pattern of significance of the amount of variance accounted for by the computerized experimental and neuropsychological measures when processing speed was controlled for in the regression analyses. There was also no change to the pattern of executive function predictors across measures when processing speed was accounted for in the analyses.

education ($t = 3.78, p < .001$) were the only significant predictors of EPT performance after controlling for the other variables. There were no significant neuropsychological predictors for any of the functional status measures.

Discussion

In this study, we examined the influence of executive function subcomponents (i.e., task switching, inhibition, and updating) on everyday functioning in healthy aging. We found that executive function measures assessing subcomponents of executive functioning showed sensitivity to the healthy aging process. In contrast, there were fewer age differences on cognitive measures assessing language, memory, and visuospatial abilities. Although this could reflect the sensitivity of the tasks used to measures the other cognitive domains, the results are consistent with the aging literature in suggesting that subclinical executive deficits exist with advanced age and may have implications for everyday functioning (e.g., Albert, Moss, Tanzi, & Jones, 2001; Ready, Ott, Grace, & Cahn-Weiner, 2003).

On the proxy measures of functional status, neither the old-old older adults nor their informants reported significantly more difficulties with everyday activities on the IADL-C compared to the young-old older adults. This contrasts with a recent study that used the same instrument and found that old-old adults were reported by their informants to have more cognitive difficulties than young-old adults (Schmitter-Edgecombe, Parsey, & Lamb, 2014). However, the sample size for the current study was smaller, and the old-old group was younger than that of the prior study, with many of the older adults in the current study endorsing close to full independence, limiting the variance and sensitivity of this measure with this cognitively healthy sample. The performance-based measures, however, showed sensitivity to the healthy aging process. The old-old older adult group performed significantly poorer than the young-old group on both administered performance-based measures (i.e., UPSA, EPT).

The findings may suggest that subtle functional difficulties in cognitively healthy old-old older adults may be better captured with performance-based measures compared to either self- or informant-report questionnaires. However, there is currently no agreed-upon or best proxy for everyday functioning as both performance-based measures and questionnaires have their strengths and weaknesses. It has previously been suggested that questionnaires and performance-based measures of everyday functioning may assess different aspects of functional abilities (Schmitter-Edgecombe et al., 2011), indicating that both may provide important information about everyday functioning. Consistent with this idea and with other prior studies with HOAs (e.g., Kempen, Steverink, Ormel, & Deeg, 1996; Reuben, Valle, Hays, & Siu, 1995), we found that neither the self- nor informant-report questionnaires correlated with either of the performance-based measures, which did correlate. Furthermore, as detailed below, although the switching subcomponent was an important predictor for both a questionnaire and performance-based measure, updating emerged as a significant predictor only for the performance-based tasks. This may suggest that these functional status measures are not assessing completely overlapping constructs and that the limitations of poor updating might be more apparent when completing accuracy-driven performance-based tasks in the

laboratory as compared to tasks that occur across longer timeframes in the everyday environment.

Similar to other multifactorial models of executive functioning (e.g., Fisk & Sharp, 2004; Friedman et al., 2008; Hull, Martin, Beier, Lane, & Hamilton, 2008; Miyake, 2000; Vaughan & Giovanello, 2010), when executive functioning subcomponents were measured using computerized experimental tests designed to better isolate the specific process of interest, circumscribed executive function subcomponents emerged. In contrast, all three neuropsychological measures of executive functioning were significantly correlated suggesting some overlap in the cognitive abilities being measured. Similarly, when examining relationships between the computerized experimental and neuropsychological measures of the same executive function subcomponent, we found that, although the updating measures correlated and the switching measures approached significance, the inhibition measures did not correlate. This could reflect differences in the two inhibition measures (behavioral versus oculomotor) or may suggest that the experimental and neuropsychological measures are not measuring the same constructs. This further reflects the task impurity problems associated with executive functioning measures. However, only one executive function measure (i.e., Reading Span) significantly correlated with neuropsychological measures assessing other domains of cognitive function (memory, language, visuospatial abilities), suggesting relatively independent measurement of executive function abilities in comparison to other cognitive domains.

Results from the regression analyses revealed that, after controlling for the other predictors, switching as measured by Trails B was a significant predictor of informant-report and the performance-based problem-solving measure (i.e., EPT), and approached significance for the behavior simulation measure (i.e., UPSA). These findings are consistent with prior research showing that switching abilities are important for functional abilities in HOAs (e.g., Bell-McGinty et al., 2002) and individuals with cognitive impairment (e.g., McAlister, Schmitter-Edgecombe, & Lamb, 2016; Yeh et al., 2011). Moreover, in contrast with several other studies of HOAs (i.e., Jefferson et al, 2006; Han, 2010), the results from the regression analyses did not show inhibition abilities to be strong predictors of everyday functioning despite both of our inhibition tasks likely measuring different aspects of inhibition (behavioral versus oculomotor). Regression analyses revealed that updating was a significant predictor for both of the performance-based measures (UPSA and EPT) after controlling for the other predictors, but not for the questionnaire measures. Although this may have been due to the limited variance within the questionnaires for the cognitively healthy older adults, limitations of poor updating might be more significant when completing time-limited, accuracy-driven performance-based tasks in the laboratory. Despite its importance, relatively few studies have examined updating abilities independent of working memory conceptualizations or considered its relationship with everyday functioning, and further research appears warranted. Consistent with prior research (e.g., Schmitter-Edgecombe et al., 2011), results from the regression analyses using the neuropsychological measures of memory, language, and visuospatial abilities found that none of the neuropsychological measures emerged as significant predictors of functional status after controlling for the other predictors.

With the exception of self-report, findings from the regression analyses showed that the neuropsychological measures of executive functioning accounted for 19% to 23% of the variance in functional status measures above demographic variables. In contrast, when using the computerized experimental measures of executive functioning that allowed for better isolation of executive subcomponents, a nonsignificant 2% to 9 % of the variance in functional status was accounted for above demographic variables. This may suggest that the neuropsychological measures of executive functioning may be capturing additional cognitive abilities as well as lower-level within domain abilities or more complex domains of executive functioning (e.g., planning). For example, in addition to Trails B involving switching, processing speed, and visuomotor abilities, our findings showed that it also correlated with measures of inhibition and updating. However, despite the neuropsychological measures of executive functioning isolating the individual executive subprocesses less than the experimental measures, our findings suggest that the neuropsychological measures were better for predicting functional abilities than the experimental measures. Given that additional variance in everyday functioning still remained to be accounted for, future work is also needed to better understand noncognitive and other cognitive correlates (e.g., social, physical, psychiatric, behavioral, environmental, and demographic factors) and their impact on the relationship between cognition and everyday functioning (e.g., direct, additive).

Regarding limitations, our sample was predominantly Caucasian, and given our small sample size, the results need to be replicated. Generalizability may be further limited as our sample was highly educated, and executive function measures are sensitive to education effects. Furthermore, as variance in neurocognitive and functional status measures tends to be more constricted in cognitively healthy samples, these findings cannot be generalized to neurologic populations, and future research is needed. Given that a large number of regression analyses were performed without adopting a more conservative alpha level, some of the findings could be significant by chance, and replication of these findings is warranted. Findings from the regression analyses were also limited by sample size, the limited battery of neuropsychological tests administered, and the specific neuropsychological measures chosen as the predictor variables to represent the cognitive constructs. Therefore, replication with other executive function measures and a larger sample size is warranted. Computerized measures commonly used in the cognitive psychology literature and explicitly designed to better isolate the executive processing subcomponents of interest (e.g., subtraction of two similar conditions except the one process of interest) were chosen to represent our experimental tasks. In contrast, our neuropsychological measures of executive function were chosen from measures that have been used to represent these executive subcomponents in the clinical research literature with patient populations. However, it is difficult to distinguish between these types of measures as there are inherent limits to the continuum of how much a measure can truly isolate a particular cognitive process without the influence of other basic cognitive processes (e.g., attention). In addition, other executive processes (e.g., flexibility and access to long term memory, planning, dual tasking/divided attention, and judgment) have also been considered important subcomponents of executive functioning (e.g., Adrover-Roig, Sese, Barcelo, & Palmer, 2012; Fisk & Sharp, 2004; Brandt et al., 2009), and models considering these will be important in future research. Furthermore, although participants in

this study were generally in good physical health, non-cognitive physical limitations that might limit everyday functioning (e.g., mobility issues) should be better assessed in future studies.

In this study, age-related differences were found on executive functioning subcomponent abilities and performance-based functional measures. Consistent with prior research, switching abilities predicted functional status performance; however, we did not replicate prior research of a relationship with inhibition. Updating abilities predicted functional status as measured by the performance-based measures but not the questionnaires, suggesting that the impact of updating may be more importance when functional status is being tested with performance-based measures but further research is needed. After controlling for age and education, the neuropsychological measures of executive functioning, but not the experimental executive function measures, explained a significant amount of variance in the functional status measures. The data suggest that the contribution of executive functioning to everyday functioning in cognitively healthy older adults when measured with more process pure experimental measures was not as strong as hypothesized. Further research is needed to determine the value of isolating executive functioning subcomponents in neuropsychological assessment and the prediction of functional abilities in older adults.

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References

- Albert MS, DeKosky ST, Dickson D, Dubois B, Feldman HH, Fox NC, Phelps CH. The diagnosis of mild cognitive impairment due to Alzheimer's disease: Recommendations from the National Institute on Aging Alzheimer's Association workgroups on diagnostic guidelines for Alzheimer's disease. *Alzheimer's and Dementia: The Journal of the Alzheimer's Association*. 2011; 7:270–279. doi:10.1016/j.jalz.2011.03.008.
- Albert MS, Moss MB, Tanzi R, Jones K. Preclinical prediction of AD using neuropsychological tests. *Journal of the International Neuropsychological Society*. 2001; 7:631–639. doi.org/10.1017/S1355617701755105. [PubMed: 11459114]
- Adrover-Roig D, Sesé A, Barceló F, Palmer A. A latent variable approach to executive control in healthy ageing. *Brain and Cognition*. 2012; 78:284–299. doi:10.1016/j.bandc.2012.01.005. [PubMed: 22296984]
- American Psychiatric Association. *Diagnostic and statistical manual of mental disorders*. 4th edition, text revision. Author; Washington, DC: 2000.
- Bell-McGinty S, Podell K, Franzen M, Baird AD, Williams MJ. Standard measures of executive function in predicting instrumental activities of daily living in older adults. *International Journal of Geriatric Psychiatry*. 2002; 17:828–834. doi:10.1002/gps.646. [PubMed: 12221656]
- Benton, AL.; Sivan, AB.; Hamsher, K. de S.; Varney, NR.; Spreen, O. *Contributions to neuropsychological assessment. A clinical manual*. 2nd ed.. Oxford University Press; New York: 1994.
- Brandt, J.; Folstein, M. *Telephone Interview for Cognitive Status*. Psychological Assessment Resources, Inc.; Lutz, FL: 2003.

- Burgess, P.; Shallice, T. The Hayling and Brixton Tests. Thames Valley Test Company; Bury St Edmunds, UK, England: 1997.
- Cahn-Weiner DA, Boyle PA, Malloy PF. Tests of executive function predict instrumental activities of daily living in community-dwelling older individuals. *Applied Neuropsychology*. 2002; 9(3):187–191. [PubMed: 12584085]
- Cahn-Weiner DA, Malloy PF, Boyle PA, Marran M, Salloway S. Prediction of functional status from neuropsychological tests in community-dwelling elderly individuals. *The Clinical Neuropsychologist*. 2000; 14(2):187–195. [PubMed: 10916193]
- Collette F, Van der Linden M. Brain imaging of the central executive component of working memory. *Neuroscience and Biobehavioral Reviews*. 2002; 26:105–125. [PubMed: 11856556]
- Dafters RI. Chronic ecstasy (MDMA) use is associated with deficits in task-switching but not inhibition or memory updating executive functions. *Drug and Alcohol Dependence*. 2006; 83:181–184. doi:10.1016/j.drugalcdep.2005.11.006. [PubMed: 16316723]
- Daigneault S, Braun CMJ, Whitaker HA. Early effects of normal aging on perseverative and non-perseverative prefrontal measures. *Developmental Neuropsychology*. 1992; 8(1):99–114.
- Daneman M, Carpenter PA. Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*. 1980; 19:450–466.
- Dempster FN. The rise and fall of the inhibitory mechanism: Toward a unified theory of cognitive development and aging. *Developmental Review*. 1992; 12:45–75.
- Farias ST, Cahn-Weiner DA, Harvey DJ, Reed BR, Mungas D, Kramer JH, Chui H. Longitudinal changes in memory and executive functioning are associated with longitudinal change in instrumental activities of daily living in older adults. *The Clinical Neuropsychologist*. 2009; 23:446–461. doi:10.1080/13854040802360558. [PubMed: 18821181]
- Farias ST, Mungas D, Jagust W. Degree of discrepancy between self and other-reported everyday functioning by cognitive status: Dementia, mild cognitive impairment, and healthy elders. *International Journal of Geriatric Psychiatry*. 2005; 20:827–834. doi:10.1002/gps.1367. [PubMed: 16116577]
- Fisk JE, Sharp CA. Age-related impairment in executive functioning: Updating, inhibition, shifting, and access. *Journal of Clinical and Experimental Neuropsychology*. 2004; 26(7):874–890. [PubMed: 15742539]
- de Frias CM, Dixon RA, Strauss E. Characterizing executive functioning in older special populations: From cognitively elite to cognitively impaired. *Neuropsychology*. 2009; 23(6):778–791. doi:10.1037/a0016743. [PubMed: 19899836]
- Friedman NP, Miyake A, Robinson JL, Hewitt JK. Developmental trajectories in toddlers' self-restraint predict individual differences in executive functions 14 years later: A behavioral genetic analysis. *Developmental Psychology*. 2011; 47(5):1410–1430. doi:10.1037/a0023750. [PubMed: 21668099]
- Friedman NP, Miyake A, Young SE, DeFries JC, Corley RP, Hewitt JK. Individual differences in executive functions are almost entirely genetic in origin. *Journal of Experimental Psychology: General*. 2008; 137(2):201–225. doi:10.1037/0096-445.137.2.201. [PubMed: 18473654]
- Ginani GE, Tufik S, Bueno OFA, Pradella-Hallinan M, Rusted J, Pompéia S. Acute effects of donepezil in healthy young adults underline the fractionation of executive functioning. *Journal of Psychopharmacology*. 2011; 25(11):1508–1516. doi:10.1177/0269881110391832. [PubMed: 21262858]
- Gold DA. An examination of instrumental activities of daily living assessment in older adults and mild cognitive impairment. *Journal of Clinical and Experimental Neuropsychology*. 2012; 34(1):11–34. doi:10.1080/13803395.2011.614598. [PubMed: 22053873]
- Goverover Y. Categorization, deductive reasoning, and self-awareness: Association with everyday competence in persons with acute brain injury. *Journal of Clinical and Experimental Neuropsychology*. 2004; 26:737–749. doi:10.1080/13803390490509321. [PubMed: 15370372]
- Han, A. Executive function as a predictor of instrumental activities of daily living (IADLs) in community-dwelling older adults (Unpublished master's thesis). University of Kansas City Medical Center; Kansas City, Kansas: 2010.

- Hedden T, Yoon C. Individual differences in executive processing predict susceptibility to interference in verbal working memory. *Neuropsychology*. 2006; 20(5):511–528. doi: 10.1037/0894-4105.20.5.511. [PubMed: 16938014]
- Hull R, Martin RC, Beier ME, Lane D, Hamilton AC. Executive function in older adults: A structural equation modeling approach. *Neuropsychology*. 2008; 22(4):508–522. doi: 10.1037/0894-4105.22.4.508. [PubMed: 18590362]
- Ivnik RJ, Malec JF, Smith GE, Tangalos EG, Petersen RC. Neuropsychological testing norms above age 55: COWAT, BNT, MAE TOKEN, WRAT-R Reading, AMNART, Stroop, TMT, and JLO. *The Clinical Neuropsychologist*. 1996; 10:262–278.
- Jefferson AL, Paul RH, Ozonoff A, Cohen RA. Evaluating elements of executive functioning as predictors of instrumental activities of daily living (IADLs). *Archives of Clinical Neuropsychology*. 2006; 21:311–320. doi:10.1016/j.acn.2006.03.007. [PubMed: 16814980]
- Kaplan, EF.; Goodglass, H.; Weintraub, S. *The Boston Naming Test*. 2nd ed.. Lea & Febiger; Philadelphia, PA: 1983.
- Lewis MS, Miller LS. Executive control functioning and functional ability in older adults. *The Clinical Neuropsychologist*. 2007; 21:274–285. doi:10.1080/13854040500519752. [PubMed: 17455018]
- Mausbach BT, Harvey PD, Goldman SR, Jeste DV, Patterson TL. Development of a brief scale of everyday functioning in person with serious mental illness. *Schizophrenia Bulletin*. 2007; 33(6): 1364–1372. doi:10.1093/schbul/sbm014. [PubMed: 17341468]
- McAlister C, Schmitter-Edgecombe M. Naturalistic assessment of executive function and everyday multitasking in healthy older adults. *Aging, Neuropsychology, and Cognition*. 2013; 20(6):735–756. doi:10.1080/13825585.2013.781990.
- McAlister C, Schmitter-Edgecombe M, Lamb R. Examination of variables that may affect the relationship between cognition and functional status in individuals with mild cognitive impairment: A meta-analysis. *Archives of Clinical Neuropsychology*. 2016 doi:10.1093/arclin/acv089.
- Miyake A, Friedman NP, Emerson MJ, Witzki AH, Howerter A, Wager TD. The unity and diversity of executive functions and their contributions to complex “Frontal Lobe” tasks: A latent variable analysis. *Cognitive Psychology*. 2000; 41:49–100. doi:10.1006/cogp.1999.0734. [PubMed: 10945922]
- Monsell S. Task switching. *Trends in Cognitive Science*. 2003; 7(3):134–140. doi:10.1016/S1364-6613(03)00028-7.
- Morris N, Jones DM. Memory updating in working memory: The role of the central executive. *British Journal of Psychology*. 1990; 81:111–121.
- Novakovic-Agopian T, Chen AJ-W, Rome S, Rossi A, Abrams G, D'Esposito M, Castelli H. Assessment of subcomponents of executive functioning in ecologically valid settings: The Goal Processing Scale. *The Journal of Head Trauma Rehabilitation*. 2014; 29(2):136–146. doi:10.1097/HTR.0b013e3182691b15. [PubMed: 23076096]
- Packwood S, Hodgetts HM, Tremblay S. A multisperspective approach to the conceptualization of executive functions. *Journal of Clinical and Experimental Neuropsychology*. 2011; 33:456–470. doi:10.1080/13803395.2010.533157. [PubMed: 21271425]
- Patterson TL, Goldman S, McKibbin CL, Hughs T, Jeste DV. UCSD Performance-Based Skills Assessment: Development of a new measure of everyday functioning for severely mentally ill adults. *Schizophrenia Bulletin*. 2001; 27(2):235–245. [PubMed: 11354591]
- Ready RE, Ott BR, Grace J, Cahn-Weiner DA. Apathy and executive dysfunction in mild cognitive impairment and Alzheimer disease. *American Journal of Geriatric Psychiatry*. 2003; 11(2):222–228. doi:10.1097/00019442-200303000-00013. [PubMed: 12611752]
- Reisberg B, Shulman MB, Torossian C, Leng L, Zhu W. Outcome over seven years of healthy adults with and without subjective cognitive impairment. *Alzheimer's & Dementia*. 2010; 6:11–24.
- Reitan, RM.; Wolfson, D. *The Halstead-Reitan Neuropsychological Test Battery: Therapy and clinical interpretation*. Neuropsychological Press; Tucson, AZ: 1985.
- Roberts RJ, Hager LD, Heron C. Prefrontal cognitive processes: Working memory and inhibition in the antisaccade task. *Journal of Experimental Psychology: General*. 1994; 123:374–393.

- Rogers RD, Monsell S. Costs of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology: General*. 1995; 124:207–231.
- Schmitter-Edgecombe M, Parsey CM. Assessment of functional change and cognitive correlates in the progression from healthy cognitive aging to dementia. *Neuropsychology*. 2014; 28(6):881–893. doi:10.1037/neu0000109. [PubMed: 24933485]
- Schmitter-Edgecombe M, Parsey C, Cook DJ. Cognitive correlates of functional performance in older adults: Comparison of self-report, direct observation, and performance-based measures. *Journal of the International Neuropsychological Society*. 2011; 17:853–864. doi:10.1017/S1355617711000865. [PubMed: 21729400]
- Schmitter-Edgecombe M, Parsey C, Lamb R. Development and psychometric properties of the Instrumental Activities of Daily Living: Compensation Scale. *Archives of Clinical Neuropsychology*. 2014; 29(8):776–792. doi:10.1093/arclin/acu053. [PubMed: 25344901]
- Schmitter-Edgecombe M, Vesneski M, Jones D. Aging and word finding: A comparison of discourse and nondiscourse tests. *Archives of Clinical Neuropsychology*. 2000; 15:479–493. doi:10.1016/S0887-6177(99)00039-6. [PubMed: 14590203]
- Snyder HR. Major depressive disorder is associated with broad impairments on neuropsychological measures of executive function: A meta-analysis and review. *Psychological Bulletin*. 2013; 139(1): 81–132. doi:10.1037/a0028727. [PubMed: 22642228]
- Tucker-Drob EM. Neurocognitive functions and everyday functions change together in old age. *Neuropsychology*. 2011; 25(3):368–377. doi:10.1037/a0022348. [PubMed: 21417532]
- Teng E, Becker BW, Woo E, Cummings JL, Lu PH. Subtle deficits in instrumental activities of daily living in subtypes of mild cognitive impairment. *Dementia and Geriatric Cognitive Disorders*. 2010; 30:189–197. doi:10.1159/000313540. [PubMed: 20798539]
- Teuber HL. Unity and diversity of frontal lobe functions. *Acta Neurobiologiae Experimentalis*. 1972; 32(2):615–656. [PubMed: 4627626]
- Vaughan L, Giovanello K. Executive function in daily life: Age-related influences of executive processes on instrumental activities of daily living. *Psychology and Aging*. 2010; 25(2):343–355. doi:10.1037/a0017729. [PubMed: 20545419]
- Vazzana R, Bandinelli S, Lauretani F, Volpato S, Lauretani F, Di Iorio A, Ferrucci L. Trail Making Test predicts physical impairment and mortality in older persons. *Journal of the American Geriatrics Society*. 2010; 58(4):719–723. doi:10.1111/j.1532-5415.2010.02780.x. [PubMed: 20398153]
- Verhaeghen P, De Meersman L. Aging and the Stroop effect: A meta-analysis. *Psychology and Aging*. 1998; 13(1):120–126. doi.org/10.1037/0882-7974.13.1.120. [PubMed: 9533194]
- West RL. An application of prefrontal cortex function theory to cognitive aging. *Psychological Bulletin*. 1996; 120(2):272–292. [PubMed: 8831298]
- Williams, JM. *Memory Assessment Scales professional manual*. Psychological Assessment Resources; Odessa, FL: 1991.
- Willis SL, Allen-Burge R, Dolan MM, Bertrand RM, Yesavage J, Taylor JL. Everyday problem solving among individuals with Alzheimer's disease. *The Gerontologist*. 1998; 38(5):569–577. [PubMed: 9803645]
- Willis, S.; Marsiske, M. *Manual for the Everyday Problems Test*. Department of Human Development and Family Studies, Pennsylvania State University; University Park: 1993.
- Yeh Y-C, Lin K-N, Chen W-T, Lin C-Y, Chen T-B, Wang P-N. Functional disability profiles in amnesic mild cognitive impairment. *Dementia and Geriatric Cognitive Disorders*. 2011; 31:225–232. doi:10.1159/000326910. [PubMed: 21474931]
- Yntema DB. Keeping track of several things at once. *Human Factors*. 1963; 5:7–17. [PubMed: 14002586]

Table 1

Demographic Data for the Younger and Older Adult Groups

Variable or test	Younger adults <i>N</i> = 70 ^a		Young-old HOA <i>N</i> = 45		Old-old HOA <i>N</i> = 25		<i>F</i>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Age	20.59	2.53	67.53	4.19	78.84	3.33	1387.17 ^{**}	YA<YO<OO
Range	18 – 28		61 – 74		75 – 87			
Education	14.94	.93	17.11	2.37	17.00	2.89	5.38 [*]	YA<YO=OO
Gender	13 F, 4 M		32 F, 13 M		13 F, 12 M			

Note.

^a
n = demographic data for 17 participants.^{*}
p < .01.^{**}
p < .001

Mean Summary Data for the Experimental and Neuropsychological Measures of Executive Function, and Other Neuropsychological Measures for the Younger and Older Adult Groups

Table 2

Test	Younger adults <i>N</i> = 70			Young-old HOA <i>N</i> = 45			Old-old HOA <i>N</i> = 25		
	<i>M</i>	<i>SD</i>		<i>M</i>	<i>SD</i>		<i>M</i>	<i>SD</i>	<i>F</i>
Experimental Executive									
Antisaccade	80.05	13.25		77.86 ^a	13.34		66.58 ^b	16.76	28.08***
Keep Track Task	22.16	2.32		20.31	2.18		16.76	4.27	36.43***
Number Letter Task ^f	.65 ^d	.36		.92 ^c	.40		1.02 ^b	.34	12.77***
Neuropsychological Executive									
Hayling ^f	7.06	16.53		25.30 ^c	23.39		31.16	22.96	18.48***
Reading Span	43.89	6.45		40.62	7.01		34.12	8.21	18.25***
Trails B ^f	25.76 ^g	15.45		37.49 ^a	19.63		69.16	58.84	13.69***
Neuropsychological Other									
MAS delayed prose	6.13 ⁱ	1.41		6.91	1.10		5.92	1.50	5.46***
Boston Naming Test	50.33 ⁱ	9.22		58.14 ^c	2.29		56.48	2.99	16.98***
Facial Recognition Test	48.07 ⁱ	3.26		48.02	3.75		47.32	3.75	.33

Note. MAS = Memory Assessment Scale.

^e*n* = 67.

^f*n* = 68.

^h*n* = 15.

^a*n* = 43.

^b*n* = 24.

^c*n* = 44.

^d*n* = 69.

^g*n* = 37.

 $p < .001$.
Trails B-A; higher scores represent poorer performance.

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Table 3

Mean Summary Data for the Functional Status Measures for the Older Adult Groups

Functional Status Measures	Young-old HOAs <i>N</i> = 45		Old-old HOAs <i>N</i> = 25		<i>t</i> -test	Cohen's <i>d</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Self-report IADL-C ^{<i>t</i>}	.11 ^{<i>d</i>}	.11	.12 ^{<i>f</i>}	.10	-.46	.10
KI-report IADL-C ^{<i>t</i>}	.14 ^{<i>e</i>}	.17	.16 ^{<i>g</i>}	.20	-.34	.11
UPSA	86.53	8.10	80.32	11.69	2.62 ^{<i>*</i>}	.62
EPT	25.04	2.33	22.00	5.12	3.38 ^{<i>**</i>}	.76

Note. IADL-C = Instrumental Activities of Daily Living: Compensation Scale. KI = knowledgeable informant. UPSA = UCSD Performance-Based Skills Assessment-Brief. EPT = Everyday Problems Test.

^{*a*}*n* = 63.

^{*b*}*n* = 52.

^{*c*}*n* = 68.

^{*d*}*n* = 40.

^{*e*}*n* = 31.

^{*f*}*n* = 23.

^{*g*}*n* = 21.

^{*t*}Higher scores represent poorer performance.

^{*‡*}Log-transformed total score.

^{***}*p* < .05.

^{****}*p* < .01.

Table 4
Intercorrelations Amongst Experimental and Neuropsychological Measures for Older Adults

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Experimental Executive									
1. Antisaccade	-	.27 ^a	-.10 ^b	-.15 ^c	-.36 ^{b*}	.19 ^a	.05 ^a	.24 ^a	.19 ^c
2. Keep Track Task		-	-.30 ^d	-.13 ^e	-.43 ^{d*}	.53 [*]	.23	.09	.30
3. Number Letter Task ^f			-	.14 ^a	.23 ^c	-.29 ^d	-.13 ^d	-.02 ^d	-.08 ^a
Neuropsychological Executive									
4. Hayling ^f				-	.42 ^{d*}	-.31 ^{e*}	.06 ^e	.02 ^e	-.09 ^d
5. Trails B ^f					-	-.53 ^{d*}	-.17 ^d	-.24 ^d	-.13 ^a
6. Reading Span						-	.36 [*]	.01	.43 ^{e*}
Neuropsychological Other									
7. MAS delayed prose							-	.09	.30 ^e
8. Facial Recognition Test								-	.18 ^e
9. Boston Naming Test									-

Note. MAS = Memory Assessment Scale.

^a *n* = 67.

^b *n* = 65.

^c *n* = 66.

^d *n* = 68.

^e *n* = 69.

^f Higher scores represent poorer performance.

* *p* < .01.

Table 5

Intercorrelations Amongst Functional Status Measures for the Older Adult Group

	Self-report IADL-C	KI-report IADL-C	UPSA total	EPT
Self-report IADL-C ^{t‡}	-	.17 ^a	-.19 ^b	.03 ^c
KI-report IADL-C ^{t‡}		-	-.14 ^d	-.26 ^e
UPSA total score			-	.50 ^{f*}
EPT				-

Note. IADL-C = Instrumental Activities of Daily Living: Compensation Scale. KI = knowledgeable informant. UPSA = UCSD Performance-Based Skills Assessment-Brief. EPT = Everyday Problems Test.

^a
n = 46.

^b
n = 63.

^c
n = 61.

^d
n = 52.

^e
n = 51.

^f
n = 68.

^t Higher scores represent poorer performance.

[‡] Log-transformed total score.

^{*}
p < .001.

Table 6

Correlations Between Functional Status Measures with Demographic, Experimental and Neuropsychological Executive, and other Neuropsychological Predictors for the Older Adult Group

	Self total ^{a†‡}	KI total ^{b†‡}	UPSA total ^c	EPT ^d
Demographics				
Age	.08	.13	-.33**	-.43***
Education	-.25*	-.20	.08	.42***
Experimental Executive				
Antisaccade	.04	-.10	.18	.21
Keep Track Task	-.03	-.06	.33**	.45***
Number Letter Task ^t	.13	.05	-.32**	-.11
Neuropsychological Executive				
Hayling ^t	.04	.21	-.08	-.12
Reading Span	-.09	-.12	.53***	.51***
Trails B ^t	.10	.46**	-.45***	-.66***
Neuropsychological Other				
MAS delayed prose	-.11	.03	.35**	.42***
Facial Recognition Test	-.14	.00	.22	.31*
Boston Naming Test	-.01	-.02	.23	.40**

Note. MAS = Memory Assessment Scale. IADL-C = Instrumental Activities of Daily Living: Compensation Scale. KI = knowledgeable informant. UPSA = UCSD Performance-Based Skills Assessment-Brief. EPT = Everyday Problems Test.

^a $n = 60 - 63$.

^b $n = 49 - 52$.

^c $n = 67-70$.

^d $n = 65 - 68$.

^t Higher scores represent poorer performance.

[‡] Log-transformed total score.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 7

Summary of Hierarchical Regression Analyses for the Experimental and Neuropsychological Executive, and other Neuropsychological Predictors of Functional Status for the Older Adult Group

Variables	Functional Status Measures			
	Self total ^t	KI total ^t	UPSA total	EPT
Experimental Executive				
<i>Model 1</i>				
Age	.00	.00	-.48 [*]	-.22 ^{***}
Education	-.01	-.02	.29	.60 ^{***}
R^2	.07	.07	.11	.32
F for R^2	2.13	1.58	3.71 [*]	14.17 ^{***}
<i>Model 2</i>				
Age	.00	.00	-.19	-.16 [*]
Education	-.01	-.01	.10	.58 ^{**}
Antisaccade	.00	.00	.06	.00
Keep Track Task	.01	.01	.49	.30 [*]
Number Letter Task ^t	.04	.00	-5.86	.86
Change in R^2	.06	.02	.09	.05
Total R^2	.13	.08	.20	.37
Neuropsychological Executive				
<i>Model 1</i>				
Age	.00	.00	-.50 ^{**}	-.25 ^{***}
Education	-.01	-.01	.35	.57 ^{**}
R^2	.07	.05	.12	.35
F for R^2	2.24	1.11	4.36 [*]	16.86 ^{***}
<i>Model 2</i>				
Age	.00	.00	-.04	-.10
Education	-.01	.00	-.15	.36 [*]
Hayling ^t	.00	.00	.06	.02
Reading Span	.00	.01	.54 ^{**}	.08
Trails B ^t	.00	.00 ^{**}	-.06	-.05 ^{***}
Change in R^2	.00	.21 [*]	.23 ^{***}	.19 ^{***}
Total R^2	.07	.26	.35	.54
Neuropsychological Other				
<i>Model 1</i>				
Age	.00	.00	-.49 ^{**}	-.24 ^{***}

Variables	Functional Status Measures			
	Self total ^{t¥}	KI total ^{t¥}	UPSA total	EPT
Education	-.01 [*]	-.01	.26	.60 ^{***}
R^2	.08	.05	.12	.35
F for R^2	2.62	1.37	4.29 [*]	17.56 ^{***}
<i>Model 2</i>				
Age	.00	.01	-.33	-.14 ^{***}
Education	-.01 [*]	-.01	.13	.54 ^{***}
MAS delayed prose	-.01	.02	1.59	.52
Facial Recognition Test	.00	.00	.32	.15
Boston Naming Test	.01	.00	.07	.21
Change in R^2	.03	.01	.06	.09 [*]
Total R^2	.11	.07	.18	.44

Note. Age and education were entered in Block 1. MAS = Memory Assessment Scale. IADL-C = Instrumental Activities of Daily Living: Compensation Scale. KI = knowledgeable informant. UPSA = UCSD Performance-Based Skills Assessment-Brief. EPT = Everyday Problems Test.

^t Higher scores represent poorer performance.

[¥] Log-transformed total score.

^{*} $p < .05$.

^{**} $p < .01$.

^{***} $p < .001$.