Published in final edited form as:

Neuropsychol Dev Cogn B Aging Neuropsychol Cogn. 2013 November ; 20(6): 735–756. doi: 10.1080/13825585.2013.781990.

Naturalistic Assessment of Executive Function and Everyday Multitasking in Healthy Older Adults

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Abstract

Everyday multitasking and its cognitive correlates were investigated in an older adult population using a naturalistic task, the Day Out Task. Fifty older adults and 50 younger adults prioritized, organized, initiated and completed a number of subtasks in a campus apartment to prepare for a day out (e.g., gather ingredients for a recipe, collect change for a bus ride). Participants also completed tests assessing cognitive constructs important in multitasking. Compared to younger adults, the older adults took longer to complete the everyday tasks and more poorly sequenced the subtasks. Although they initiated, completed, and interweaved a similar number of subtasks, the older adults demonstrated poorer task quality and accuracy, completing more subtasks inefficiently. For the older adults, reduced prospective memory abilities were predictive of poorer task sequencing, while executive processes and prospective memory were predictive of inefficiently completed subtasks. The findings suggest that executive dysfunction and prospective memory difficulties may contribute to the age-related decline of everyday multitasking abilities in healthy older adults.

Keywords

Ecological Validity; Aging; Episodic Memory; Prospective Memory; Planning

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Throughout the expanding body of research on age-related cognitive decline, executive functions have frequently been identified as a commonly impaired domain (e.g., Treitz, Heyder, & Daum, 2007; Zelazo, Craik, & Booth, 2004). Executive functions are broadly defined as a collection of higher order supervisory control processes involved in the flexible regulation of complex goal-directed problem-solving thoughts and actions. Intact executive functions bolster a multitude of everyday, "real world" functions including planning and sequencing of complex task goals, initiating goal-directed behavior, performing multiple tasks simultaneously (multitasking), sustaining attention despite interference or distraction, and terminating behavior. In this study, a naturalistic task that requires multitasking was used to investigate executive function in healthy older adults.

While standardized laboratory tests provide important information regarding cognitive impairments, they have been criticized for being poorly conducive to the fundamental deficit imputed to executive dysfunction - the inability to deal with open-ended, poorly constrained environments that are commonly encountered in the real world (Burgess, Alderman, Evans, Emslie, & Wilson, 1998; Manchester, Priestley, & Jackson, 2004; Wilson, 1993). Interestingly, it is well known that everyday executive function deficits often exist despite

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No conflicts of interest exist.

normal performance on traditional tests of executive function. This is perhaps best illustrated in the well-cited examples of Eslinger and Damasio (1985), Penfield and Evans (1935), and Shallice and Burgess (1991).

Although much research has been dedicated to investigating specific aspects of executive function (e.g., set-shifting, planning), multitasking has only recently been investigated in detail, commonly with divergent operationalizations. For laboratory testing, the term multitasking has been used to describe rapidly switching between tasks (e.g., Law et al., 2004) as well as to describe simultaneously performing multiple tasks (e.g., Neider et al., 2011). Considered in these ways, findings suggest an age-related decline in multitasking abilities (see also Craik & Bialystok, 2006; Garden, Phillips, & MacPherson, 2001; Levine et al., 1998; Lin, Chan, Zheng, Yang, and Wang, 2007). Conversely, Logie, Law, Trawley, and Nissan (2010) described "everyday multitasking" as involving several distinct tasks with sub-goals, longer time scales with less crucial rapid and accurate response times, and individuals completing tasks in a certain order and switching as each task is completed (see also Burgess and Simons, 2005). Everyday multitasking differs from task-switching paradigms in that multiple tasks with clear end points are involved and time scales are much longer (Logie et al., 2010). It also differs from dual-task paradigms in that tasks are completed by interweaving rather than in parallel (Logie et al., 2010).

It is evident that successful execution of everyday multitasking situations relies on a number of cognitive processes, perhaps acting in concert. Using a statistical model of everyday multitasking impairments associated with frontal-lobe lesions, Burgess, Veitch, de Lacy Costello, and Shallice (2000) identified retrospective memory, prospective memory, and planning as important and largely independent constructs that support multitasking. Many traditional tests of executive function focus on isolated executive components without considering the multiple executive processes and self-initiation required for goal-directed behavior in everyday multitasking (Scott et al., 2011).

Efforts to develop more realistic everyday situations include simulations of real-life events with office-based tasks (e.g., Lamberts, Evans, & Spikman, 2010) and virtual reality (e.g., Rand, Rukan, Weiss, & Katz, 2009). In addition, naturalistic procedures have been developed following Shallice and Burgess' (1991) Multiple Errands Test (MET), which involved having neurological patients complete tasks in a real-world shopping center (e.g., Alderman, Burgess, Knight, & Henman, 2003; Knight, Alderman, & Burgess, 2002; Rand et al., 2009; Rocke, Hays, Edwards, & Berg, 2008; Sanders & Schmitter-Edgecombe, 2012). Using the MET and Virtual Multiple Errands Test (VMET), Rand et al. (2009) found that, although healthy older adults performed better than post-stroke patients on both measures, they demonstrated more total mistakes, partial mistakes, and non-efficiency mistakes compared to younger adults. Similarly, using a naturalistic task to examine planning abilities, Sanders and Schmitter-Edgecombe (2012) found that, compared to younger adults, older adults were less accurate in formulating a plan and less efficient in executing their task, interweaving fewer subtasks and completing fewer subtasks. More generally, older individuals experiencing multitasking difficulties may exhibit more mistakes, inefficiently complete tasks, or not attempt tasks because they have difficulty planning or switching between activities (Cook, 2008).

While a few studies have investigated planning and multitasking abilities in older adults using more open-ended, naturalistic situations (e.g., Rand et al., 2009; Sanders & Schmitter-Edgecombe, 2012), none have investigated the cognitive correlates related to everyday multitasking in the healthy aging population. In the present study, multitasking performances of cognitively healthy younger and older adults were compared on the "Day Out Task" (DOT, Schmitter-Edgecombe, McAlister & Weakley, 2012), a naturalistic task with a strong multitasking component aimed at assessing executive function in a real-life setting. The DOT requires participants to complete tasks that an individual might complete when preparing for a day out (e.g., collect change for a bus ride, prepare a heating pad). Most importantly, participants are instructed to multi-task and interweave the tasks in a way that feels natural and most efficient. Completion of the DOT is consistent with the definition of everyday multitasking in that participants have to prioritize competing demands and create, maintain, and initiate delayed intentions. Furthermore, participants have to switch between subtasks with an optimum order, realize delayed intentions, and decide when to begin and conclude subtasks and overall task attempts.

The goals for this study were to (1) compare everyday multitasking abilities of younger and older adults on a naturalistic task, and (2) to identify cognitive correlates of everyday multitasking abilities in the aging population. More specifically, we sought to evaluate whether the cognitive constructs identified as important in multitasking (i.e., retrospective memory, prospective memory, and planning) would account for significant variance in DOT performances. In addition, because executive functions are associated with efficient "real world" functioning, we were interested in evaluating the relationship between executive function measures and DOT performances. We expected that older adults would perform more poorly on the DOT, and that, in addition to executive function measures, retrospective memory, prospective memory, and planning would account for significant variance in DOT performance.

Method

Participants

Participants were 50 cognitively healthy older adults (ages 60–74, $M = 66.86$, $SD = 4.40$) and 50 younger adults (ages 18–33, $M = 22.15$, $SD = 1.71$). We used an age range of 60 to 74 years for the older adult group, which represents young-old participants, because the literature suggests that executive functions sharply decline after age 60 (e.g., Treitz et al., 2007). All older adult participants were community-dwelling adults who functioned independently, and did not meet criteria for Mild Cognitive Impairment as outlined by the National Institute on Aging-'s Association workgroup (Albert et al., 2011). As expected, the older adult group had a higher level of education ($M = 17.03$, $SD = 2.08$, range = 11-20), given that the younger adults were still completing their education ($M = 14.89$, $SD = 1.71$, range 12-20), $t(97) = 4.31$, $p < .001$. There was also a higher proportion of female participants in the older adult group (86%) compared to the younger adult group (58%), $X^2(1, N = 100) = 9.722$, $p < .01$. Exclusionary criteria included history of brain surgery, cerebrovascular accidents, or head trauma with permanent brain lesion; current or recent (i.e., within the past year) psychoactive substance abuse; known medical, neurological, or psychiatric causes of cognitive dysfunction; and self- or knowledgeable informant report of significant memory complaints or changes in cognitive ability across the past months two years.

Initial screening for older adult participants was conducted over the phone and included: (a) a medical interview to rule out exclusion criteria, (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), and (c) the Clinical Dementia Rating (CDR) to rule out cognitive impairment suggestive of dementia (i.e., a CDR > 0; Hughes, Berg, Danzinger, Coben, & Martin, 1982; Morris, 1993). 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 Washington State University psychology participant pool and received course credit.

Those who met initial screening criteria completed laboratory-based standardized and experimental neuropsychological tests as well as complex activities of daily living within an apartment located on the WSU campus. Both testing sessions lasted approximately 3 hours and were scheduled one week apart, with the laboratory testing typically completed first. As compensation, older adult participants were given pre-paid parking passes and a report documenting their performance on the neuropsychological tests. In addition, older adults who traveled from outside of Whitman or Latah County were provided a $50 travel reimbursement voucher. This protocol was reviewed and approved by the Institutional Review Board at WSU.

Measures

Day Out Task—The DOT is a naturalistic, everyday task that was performed in a campus apartment (see Schmitter-Edgecombe et al., 2012). Prior to completing the DOT, participants had completed other everyday tasks and were familiar with the apartment layout (e.g., living room, dining room, kitchen) and location of closets and cupboards. For the DOT, participants were told to imagine that they were planning for a day out, which included meeting a friend at a museum at 10:00 am and later traveling to the friend's house for dinner. Participants were provided with a written list of the eight subtasks (see Table 1) to be completed. The tasks were clearly explained with reference to the instruction sheet [for complete task instructions, see Schmitter-Edgecombe et al., 2012], and participants were given an opportunity to summarize and ask questions. Before beginning the DOT, participants were reminded to efficiently multi-task and interweave the tasks.

Two examiners, blind to the study hypotheses, watched participant performances from upstairs via live (recorded) video feed and communicated through an intercom system if necessary. Examiners recorded the time each subtask began and ended, events being interweaved, and subtask goals being completed (e.g., retrieves magazine). Using a 5-point Likert scale, each examiner provided a subjective rating of each participant's overall task quality and goal directedness (i.e., examiner-rated task quality and examiner-rated goal directedness) (see Table 2). There was high agreement between examiners for both task quality (kappa statistic = .90) and goal directedness (kappa statistic = .99) ratings.

Later, two coders who were blind to the study hypotheses, watched the video data in conjunction with examiner-recorded data, and assigned subtask completion scores (i.e., complete/efficient, complete/inefficient, incomplete/inaccurate, never attempted) and task sequencing scores. Data were double checked by author C.M. Detailed score assignment information for the subtask completion scores and DOT total accuracy score (i.e., sum of the eight subtasks completion scores) as well as scoring rubrics to derive the DOT task sequencing and examiner-rated task quality and goal directedness scores are provided in Table 2. A list of potential situations that resulted in each of the eight subtasks being scored as efficient, inefficient, or incomplete was generated and used for coding (see Table 3 for an example). Coders discussed new situations or errors that were not detailed on the master code list and added the new information. To assess for inter-rater reliability, total discrepancies in scoring were summed for the DOT total accuracy and DOT task sequencing scores with agreement 97.88% and 99.57%, respectively.

Multitasking variables—The multitasking predictor variables represent the three cognitive constructs prior research suggests play an essential role in multitasking (Burgess et al., 2000; Logie et al., 2010): retrospective memory, prospective memory and planning (see Table 5).

Memory Assessment Scale (MAS): Prose Memory subtest: (Williams, 1991). After hearing a three-sentence short story one time, participants were asked to answer nine questions about the story (e.g., What color was the car?) both immediately and after a long delay filled with other tasks. Retrospective memory was represented by the total number of correctly answered questions at the long delay.

Activity-Based Multiple Memory Processes Paradigm: Prospective Memory Test: (Schmitter-Edgecombe et al., 2009; Schmitter-Edgecombe et al., 2012). Prior to beginning eight separate activities of daily living (e.g., change a light bulb, cook oatmeal), participants were instructed that we wanted to see how well they could remember to do something in the future without being reminded. Participants were told that following each activity, they would be ask to rate how strenuous they found the task on a scale from '0%' (*not at all strenuous*) to '100%' (*very strenuous*). They were also told that the task strenuous rating would be their cue to remind the examiner to record the current clock time. The first activity did not begin until it was clear that the participant understood the prospective memory instructions. The activities varied in length between 5-12 minutes. No future reference to the event cue (i.e., strenuous rating) or the prospective memory task was made once the activities began. Prospective memory was represented by the number of times (eight maximum) the participant correctly reminded the examiner to record the clock time.

Behavioral Assessment of the Dysexecutive Syndrome (BADS): Zoo Map subtest: (Wilson, Alderman, Burgess, Emslie, & Evans, 1996). Participants were given a map of a zoo and sets of instructions listing places they had to visit (e.g., lion's cage) along with rules to follow (e.g., finish at the picnic area). They completed both a high-demand condition requiring formulation of a planned route through the zoo and a low-demand condition requiring execution of a predetermined route. The Zoo Map was scored in accordance with the standardized instructions of the BADS battery. Planning was represented by the Zoo Map profile score (four maximum).

Executive function and neuropsychological measures—The following predictor variables represent the cognitive constructs of executive functioning, processing speed, visuoperceptual abilities, and language abilities that were used in the regression analyses (see Table 5). The neuropsychological measures, as opposed to the executive function measures, were chosen as constructs not expected to have a significant relationship with multitasking.

Trail Making Test (TMT): (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 A and B were used as measures of processing speed and executive function, respectively.

Clox 1: (Royall, Cordes, & Polk, 1998). Participants were asked to draw a clock with the hands set to a specified time. Total score on the free drawing subtask was used as a measure of executive function.

Delis-Kaplan Executive Function System (D-KEFS): Letter Fluency and Category subtests: (Delis, Kaplan, & Kramer, 2001). Participants were asked to state as many words as they could think of within a 60 second time period that begin with a specified letter (F, A, and S) and belong to a specified category (Animals and Boys' Names). The total numbers of correct words produced for the letters F, A, and S and the categories Animals and Boys' Names were used as measures of executive function and language abilities, respectively.

Brief Visuospatial Memory Test-Revised (BVMT-R): Copy subtest: (Benedict, 1997). Participants were asked to accurately copy an array of six simple figures. Total score on the copy subtask was used as the measure of visuoperceptual abilities.

Neuropsychological measures—The following neuropsychological tests were used to describe the population of older and younger adults.

Shipley Institute of Living Scale (SILS): Vocabulary subtest: (Zachary, 1991). Participants were asked to complete 40 multiple-choice vocabulary items by choosing a word closest in meaning to a target word from among four options. Total score was used as an estimate of verbal intellectual abilities.

Symbol Digits Modalities Test (SDMT): Written and Oral subtests: (Smith, 1991). Participants were given 90 seconds to pair specific numbers with given geometric figures, both orally and in writing. Total scores from the oral and written versions were used as measures of processing speed.

Boston Naming Test (BNT): (Ivnik, Malec, Smith, Tangalos, and Petersen, 1996). Participants were asked to name line-drawings of objects that vary in level of difficulty. 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.

Results

Analyses

T-tests were used to compare the younger and older adult groups on neuropsychological variables. T-tests were also used to compare group performances on the DOT measures. In cases where the assumption of normality was not met, the non-parametric Mann-Whitney U Test was used. To indicate the relative strength of significant group differences, effect sizes (Cohen’s d) were calculated. Hierarchical regression analyses were used to examine the relationship between multitasking predictors (i.e., retrospective memory, prospective memory and planning) and DOT task performances. Hierarchical regression analyses were also used to examine the relationship between the executive measures (Trails B, Clox 1 and D-KEFS letter fluency) and DOT task performances, and between the neuropsychological measures (processing speed, visuoperceptual abilities and language) and DOT task performances. The demographic variables of age and education were entered in the first block of the regressions; gender was not entered as a predictor as there were no significant correlations between gender and the DOT measures (Spearman’s rho correlation coefficients ranged from −.21 to .17). The predictors were then entered simultaneously in the second block of the regressions. Given the exploratory nature of the regression analyses, we did not adjust for multiple analyses and set alpha at .05.

Neuropsychological data

Table 4 shows neuropsychological data for the younger and older adult groups. Consistent with the aging literature, in comparison to the younger adults, the older adults performed more poorly on tests of speeded processing (i.e., SDMT) and better on tests of word knowledge (i.e., Boston Naming and Shipley Vocabulary test). Table 5 shows the means and standard deviations for the multitasking, executive functioning and neuropsychological predictor variables used in the regression analyses with the older adults.

Day Out Task

Means and standard deviations for the measures derived from the DOT are found in Table 6. Before comparing DOT performances across age groups, we evaluated whether gender had any effect on DOT performances. With the exception of younger males (M = 8.19 minutes) taking a longer time to complete the DOT task than younger females (M = 7.07 minutes), $t(48) = 4.20$, $p < .05$, making it more difficult to find an age effect for time on task, there were no significant gender differences in DOT scores for either age group. Therefore, we did not control for gender when assessing for age differences on DOT performances. T-tests revealed no significant difference between older and younger adults, $t = -1.09$, $d = -.23$, in the amount of time that participants took to plan for the DOT. However, the older adults took significantly longer to complete the DOT compared to younger adults, $t(98) = 6.78$, $p < .01$, $d = 1.35$.

Both younger and older adults initiated, U(100) = 1,250.00, $Z = .00$, $p = 1.0$, and completed, U(100) = 877.00, $Z = 1.40$, $p = .16$, a comparable numbers of the eight subtasks of the DOT. However, the DOT total accuracy score, derived as the sum of the eight subtask completion scores (see Table 2), was significantly poorer for the older adults compared to the younger adults, $t(98) = 3.25$, $p < .01$. Similarly, the examiners rated the overall task quality of the older adults' DOT performance as poorer than that of the younger adults, U(92) = 484.00, $Z = -4.59$, $p < .001$.

To assess for group differences in DOT subtask completion, a 2 group (Older Adult, Younger Adult) by 4 subtask completion (complete/efficient, complete/inefficient, incomplete/inaccurate, never attempted) chi-square test was conducted, χ (3, $N = 800$) = 15.68, $p < .05$. Single degree of freedom tests revealed that the older adults completed significantly fewer of the subtasks completely and efficiently, χ (1, n = 532) = 5.08, $p < .05$, and significantly more of the subtasks completely and inefficiently, χ (1, n = 205) = 9.49, $p < .01$, when compared to the younger adults. There were no group differences in the number of subtasks that were left incomplete, χ (1, n = 57) = 0.86, $p = .35$. Few tasks were never attempted by both the older and younger adult groups.

Analysis of the DOT sequencing score revealed a significant difference showing that older adults more poorly sequenced the DOT subtasks during task performance compared to the younger adults, $t(98) = -4.44$, $p < .01$, $d = -.89$. Furthermore, the examiners rated the overall task directedness of the older adults' DOT performance as significantly poorer than that of the adults, U(92) = 430.50, $Z = -4.98$, $p < .001$. The groups did not significantly differ in the number of the eight subtasks that were interweaved, $t = 1.00$ (see Table 6).

Regression Analyses

Hierarchical regression analyses were conducted to investigate whether the multitasking, executive function, or neuropsychological measures could predict performance on the DOT for the older adult group. The younger adults were excluded from the analyses as few completed the laboratory measures and younger adults were not the primary focus of this study. Subtasks complete/inefficient, DOT total time, DOT total accuracy, and DOT sequencing score were used as the primary outcome measures from the DOT to represent different domains of performance. Table 7 shows correlations amongst the predictor and criterion variables. Age and education were entered in the first block. Then, the three multitasking predictors (retrospective memory, prospective memory, planning) were entered simultaneously into the second block to determine if they held any unique and predictive value for each of the DOT measures. This method was repeated with the executive functioning (Trails B, Clox 1, Letter Fluency) and neuropsychological measures (processing speed, visuoperceptual abilities, language abilities). The Variance Inflation Factors for each variable were less than 1.4 indicating no multicollinearity within the three sets of predictor variables. As several of the older adults did not complete all of the cognitive and neuropsychological measures, sample sizes for the regression analyses with the multitasking and neuropsychological predictors were 46 and 48, respectively.

Multitasking Predictors—Table 8 displays the beta coefficients for all of the predictors entered into the regression analyses. For the DOT subtasks complete/inefficient measure, although the three multitasking predictors [$\Delta F(3, 40) = 2.30$, $p = .09$] did not account for significant variance after the demographic factors were entered, $R^2 = .07$, $F(2, 43) = 1.72$, $p = .19$, prospective memory emerged as a unique predictor, $t = -2.26$, $p < .05$. The demographic variables accounted for significant variance in DOT total time, $R^2 = .14$, $F(2, 43) = 3.57$, $p < .05$, with education emerging as a unique predictor, $t = -2.13$, $p < .05$. The multitasking predictors did not account for additional significant variance in DOT total time [$\Delta F(3, 40) = .64$, $p = .60$]. Age emerged as a unique predictor, $t = 2.42$, $p < .05$, for the DOT total accuracy score, with the demographic variables accounting for significant variance, $R^2 = .15$, $F(1, 44) = 5.42$, $p < .05$. The three multitasking predictors did not account for additional significant variance in DOT total accuracy [$\Delta F(3, 40) = .60$, $p = .62$]. For the DOT sequencing score, although the multitasking predictors [$\Delta F(3, 40) = 2.61$, $p = .07$] did not account for significant variance after the demographic factors were entered, $R^2 = .06$, $F(2, 43) = 1.46$, $p = .24$, prospective memory emerged as a unique predictor, $t = 2.35$, $p < .05$.

Executive Predictors—For the DOT subtasks complete/inefficient measure, although the executive function measures [$\Delta F(3, 44) = 2.56$, $p = .07$] did not account for significant variance above the demographic factors, $R^2 = .08$, $F(2, 47) = 2.05$, $p = .14$, the letter fluency test emerged as a unique predictor, $t = -2.01$, $p = .05$ (see Table 8). The demographic variables accounted for significant variance in DOT total time, $R^2 = .14$, $F(2, 47) = 3.78$, $p < .05$, with education emerging as a unique predictor, $t = -2.05$, $p < .05$. The executive function measures did not account for significant additional variance in DOT total time [$\Delta F(3, 44) = 1.50$, $p = .23$]. For the DOT accuracy score, the executive functioning measures did not account for additional variance [$\Delta F(3, 44) = .36$, $p = .60$] above that accounted for by the demographic variables, $R^2 = .16$, $F(2,) = 4.62$, $p > .05$, and there were no unique predictors. In addition, neither the demographic variables, $R^2 = .03$, $F(2, 47) = .84$, $p = .44$, nor executive functioning predictors [$\Delta F(3, 44) = .93$, $p = .43$] accounted for significant variance for the DOT sequencing score and no variables emerged as unique predictors.

Neuropsychological Predictors—Neither the demographic variables, $R^2 = .11$, $F(2, 45) = 2.87$, $p = .07$, nor the neuropsychological variables [$\Delta F(3, 42) = .65$, $p = .59$] accounted for significant variance in the DOT complete/inefficient measure and no variables emerged as unique predictors (see Table 8). For DOT total time, the demographic variables accounted for significant variance, $R^2 = .14$, $F(2, 45) = 3.61$, $p < .05$. Although the neuropsychological predictors did not account for additional significant variance in total time [$\Delta F(3, 42) = 2.09$, $p = .12$], both education, $t = -2.24$, $p < .05$, and Trails A, $t = 2.16$, $p < .05$, emerged as unique predictors. The demographic variables accounted for significant variance for total accuracy, $R^2 = .13$, $F(2, 45) = 3.49$, $p < .05$, but the neuropsychological measures did not account for significant variance over and above that accounted for by age [$\Delta F(3, 42) = .43$, $p = .73$]. There were no unique predictors for total accuracy. Neither the demographic variables, $R^2 = .03$, $F(2, 45) = .70$, $p = .50$, nor neuropsychological measures [$\Delta F(3, 42) = .08$, $p = .97$] accounted for significant variance for the DOT sequencing score and no variables emerged as unique predictors.

In summary, processing speed and education were predictive of DOT total time whereas executive functions and prospective memory were predictive of inefficient completion of subtasks. Prospective memory also emerged as the only unique predictor of subtask sequencing.

Discussion

Much of the prior literature has focused on specific aspects of executive function but rarely the interplay between aspects needed for everyday multitasking. In this study, we compared the everyday multitasking abilities of cognitively healthy younger and older adults using a naturalistic task which required prioritization, organization, and initiation of multiple subtasks (i.e., the DOT task). We also examined the relationship between cognitive correlates and DOT measures in the older adult population. Everyday multitasking was operationalized as an individual's ability to sequence and execute multiple, distinct tasks with sub-goals where switching between tasks was recommended and simultaneous performance of tasks could be advantageous but not required.

Consistent with the aging literature, the older adults performed more poorly than the younger adults on the DOT. More specifically, although the older adults did not take longer to plan for the DOT, they took longer to complete the DOT, which is consistent with findings of slower processing speed with increasing age. In addition, the older adults more poorly sequenced the DOT subtasks (i.e., they completed fewer of the six activity sequences correctly), which is consistent with findings of age-related decline in sequencing of goal-directed actions. This was also reflected in the examiners' ratings of poorer goal directedness for the older adults. The poorer sequencing of the subtasks by the older adults may also have contributed to their longer DOT completion time.

Although the older adults initiated and completed as many of the subtasks as the younger adults and interweaved a similar number of subtasks, the DOT total accuracy score and examiner-rating of task quality was poorer for the older adults compared to the younger adults. Evaluation of subtask completion scores revealed that, compared to the younger adults, the older adults completed significantly fewer subtasks efficiently while completing significantly more subtasks inefficiently. For example, the older adults may have gathered more items than needed for their recipe or searched multiple locations for their items. That is, despite completing the subtasks and being as prepared as younger adults to leave for their day out, the older adults' preparations were much less efficient than the younger adults. These findings are similar to other multitasking studies (Craik & Bialystok, 2006; Lin et al., 2007), and importantly, other everyday multitasking studies (Rand et al., 2009; Sanders & Schmitter-Edgecombe, 2012), which have shown that older adults are generally less efficient when completing complex everyday tasks than younger adults.

We also sought to identify correlates of performance on the DOT for older adults. One prominent statistical model of everyday multitasking identified retrospective memory, prospective memory, and planning as largely independent cognitive systems involved in multitasking (Burgess et al., 2000). Results from the regression analyses using these cognitive correlates revealed that prospective memory was predictive of the DOT sequencing and DOT complete/inefficient scores for the older adults. It follows that task sequencing and efficiency would be affected if delayed intentions cannot be realized at the proper time. The regression analyses also showed that the executive function measures accounted for significant variance in subtasks completed but left inefficient, with D-KEFS letter fluency a unique predictor. This is consistent with prior studies that have found significant relationships between age-related decline in executive abilities and instrumental activities of daily living difficulties among cognitively-healthy older adults (e.g., Cahn-Weiner, Malloy, Boyle, Marran, & Salloway, 2000). These findings suggest that, along with well-known age-related executive dysfunction, difficulty initiating intentions at the proper time so that multiple goals and subgoals can be most efficiently completed may be contributing to the poorer performance of older adults in complex everyday multitasking situations. Not surprisingly, the results from the regression analyses using the neuropsychological measures of language, processing speed, and visuospatial abilities found that the only unique predictor was Trails A (processing speed) for DOT total time.

In a recent study, we found a different pattern of DOT performance difficulties when comparing individuals with mild cognitive impairment (MCI) to healthy older adult controls (Schmitter-Edgecombe et al., 2012). More specifically, the MCI and older control group generally approached the DOT in a similar manner as there were no group differences in the DOT sequencing score or the number of subtasks initiated or interweaved. However, individuals with MCI showed poorer overall accuracy. They completed significantly fewer subtasks completely and efficiently while completing significantly more subtasks incompletely and inaccurately. Retrospective memory was also found to be a unique predictor of the number of subtasks completed inaccurately and incompletely in the MCI population. Together these findings suggest that executive function difficulties resultant from normal aging, as exampled in the present study, may lead to inefficient completion of subtasks in everyday multitasking situations while significant memory difficulties may lead to more severe impairments (i.e., incomplete or inaccurate subtask completion). Consistent with the current study, prospective memory was found to be a significant predictor of DOT sequencing. Our data also suggest that the DOT measures may be capturing different aspects of everyday multitasking performances that are related to different cognitive skills. More specifically, while prospective memory may play an important role in task sequencing, executive functions may be important for reducing task inefficiencies and retrospective memory for completing tasks accurately and completely. This is consistent with research suggesting there are different cognitive systems acting in concert involved in multitasking (e.g., Burgess et al., 2000; Logie et al., 2010; Logie, Trawley, & Law, 2011), and with studies suggesting a primary role for memory and executive functioning abilities in everyday activity completion (Cahn-Weiner et al., 2007).

Regarding limitations, our samples of cognitive healthy older and younger adults came from different sources of recruitment and our older adults were highly educated and predominantly female. Furthermore, the number of possible predictor variables that could be used in the regression analyses was limited by the small study sample size and by the specific multitasking, executive functioning and neuropsychological predictor variables that were used in this study. 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 the findings is warranted. Participants also had access to a clearly written list of subtasks, which is different from many everyday situations. Finally, as the DOT is a novel and naturalistic task that may have required completion of unfamiliar tasks, it is possible that a different set of cognitive correlates may have emerged from completion of more familiar tasks.

In this study, age-related differences in everyday multitasking and executive function abilities were found between cognitively healthy older and younger adults. Although the older adults initiated and completed as many subtasks as the younger adults, older adults had a poorer sequencing score and completed more DOT subtasks inefficiently when compared to younger adults. For the older adults, reduced prospective memory abilities were predictive of the DOT sequencing score, whereas executive processes and prospective memory were predictive of the number of inefficiently completed subtasks. These findings suggest that, along with executive function deficits, prospective memory difficulties may contribute to the age-related decline of everyday multitasking abilities in healthy older adults.

Acknowledgments

This study was partially supported by grants from the Life Science Discovery Fund of Washington State; NIBIB (Grant R01 EB009675); and NSF (Grant DGE-0900781) to M.S.E.

We thank Chad Sanders, Alyssa Weakley, and Jennifer Walker for their assistance in coordinating data collection. We also thank members of the Aging and Dementia laboratory for their help in collecting and scoring the data.

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Table 1

List of Goals Given to Participants to Assist with Completion of the Day Out Task

Day Out Task
The activities below can be completed in any order. Please multi-task and interweave the tasks to complete the tasks in an efficient and natural way. When you have finished the tasks, take the picnic basket to the front door.[a]
Gather correct change from organizer on dining room table for the bus ride.
Take motion sickness medication “Dramamine” located in kitchen cupboard “A” just prior to leaving the house.
Plan bus route, determine time needed for the trip, cost of bus fare, and time that must leave house to make bus (it takes 15 minutes to walk to bus stop).
Microwave heating pad located in kitchen cupboard “B” for 5 minutes to take on bus.
Choose a magazine on coffee table for the bus ride.
Pack all items in a picnic basket, which can be found in the hallway closet labeled “clothes closet”
[b]Gather recipe items from kitchen cupboard “A” and refrigerator
[b]Locate recipe for “Spaghetti“ in recipe book, which is located in kitchen cupboard “B”
Total time for bus trip: __________
Cost of bus fare: _________
Time must leave house to get to museum by 10:00 a.m. (note: it takes 15 minutes to walk to the bus stop) ___________

Note: List was printed in 22 inch Times New Roman font

[a]counted as “exit” subtask

[b]counted as one subtask: “recipe book and ingredients”

Table 2

Coding Schema Used to Derive Measures for the Day Out Task

Subtask Completion Scores

Each of the 8 subtasks is assigned one of the following scores.

1 = *Complete/Efficient.* Assigned when subtask completed accurately and efficiently.

2 = *Complete/Inefficient.* Assigned when subtask completed in a way that the overall DOT goal can be met but subtask completion is inefficient (e.g., pretends to take pill too early, carries items to front door in hand rather than picnic basket, gathers more items than needed for recipe, searches multiple locations for items).

3 = *Incomplete/Inaccurate.* Assigned when subtask is left incomplete (e.g., fails to pack gathered item in picnic basket, fails to pretend to take pill, fails to remove heating pad from microwave) or is completed inaccurately (e.g., fails to retrieve enough change for bus, pretends to take wrong pill, grabs reading material other than magazine for bus ride).

4 = *Never Attempted.* Assigned when subtask failed to be initiated.

Total Accuracy Score

Summation of the subtask completion scores (see above) for each of the 8 subtasks (range = 8 – 32).

Task Sequencing Score

Total number of the six activities below correctly sequenced (range = 0 – 6).

1. Heating pad started as one of first four activities.
2. Picnic basket retrieved as one of first four activities.
3. Cost of bus route determined prior to first attempt at retrieving change.
4. Recipe read prior to retrieving food items.
5. Dramamine pill taken near end. (Dramamine pill is taken too early if another subtask is initiated after the Dramamine pill is taken other than the exit subtask, or another subtask is completed after the Dramamine pill subtask other than the picnic basket subtask, heating pad subtask, or exit subtask.)
6. Picnic basket moved to front door as one of last two activities.

Examiner Rating Scores

Averaged across both examiners, range = 1 - 5.

Task Quality: Characterizes overall rating for how well the DOT was carried out by the participant.

Goal Directedness: Characterizes overall rating for how well the participant remained on task and was able to use the list of tasks to quickly and efficiently move from one subtask to another.

5-Point Likert Rating Scale: 1=excellent 2=very good 3=good 4=fair 5=poor

Table 3

Example Master Coding List for Heating Pad Subtask

Heating Pad Subtask
Task Completion
• Task is complete when the heating pad is taken out of the microwave and placed in the picnic basket or brought to the front door.
Inefficient
• If the participant has to stand around and wait for the heating pad to be done in the microwave, mark the task as being inefficient.
• Mark as inefficient if the participant retrieves the heating pad from the cupboard but does not put it directly in the microwave.
• If participant is looking in multiple locations for the heating pad, mark as inefficient.
• If participant heats heating pad more than once, mark as inefficient.
Incomplete
• If the heating pad is never put in the microwave to be heated, mark the task as incomplete.
• Mark as incomplete if the participant puts the heating pad in the microwave but never retrieves it.

Table 4

Mean Neuropsychological Testing Summary Data for the Older Adult and Younger Adult Groups

	Older Adult		Younger Adult			
Variable or test	**Mean**	**SD**	**Mean**	**SD**	**t- test**	**Cohen's d**
Global Cognitive Status						
SILS Vocabulary	35.16	3.36	30.97	2.75	5.73*	1.36
TICS	35.45[a]	1.84	--	--		--
Processing Speed						
SDMT written correct	51.80	8.51	63.26	8.05	−5.54*	−1.38
SDMT oral correct	58.44	9.50	74.00	14.50	−5.51*	−1.27
Language						
BNT total correct	57.08	2.72	55.00	3.24	3.02*	.70

Notes. Unless otherwise indicated, mean scores are raw scores. Norm sources for the cognitive tests are in parentheses following the test. SILS = Shipley Institute of Living Scale (Zachary, 1991); TICS = Telephone Interview of Cognitive Status (Brandt & Folstein, 2003); SDMT = Symbol Digit Modalities Test (Smith, 1991); BNT = Boston Naming Test (Ivnik, Malec, Smith, Tangalos, & Petersen, 1996).Younger adults were not routinely given laboratory testing. Therefore, *N*'s for younger adults vary between 28 and 30.

[a]Data available for 47 of 50 participants.

*$p < .01$

Table 5

Mean Summary Data for the Multitasking, Executive Functioning, and Neuropsychological Predictors for the Older Adults.

	Older Adults	
Predictors	**Mean**	**SD**
Multitasking Predictors		
MAS Prose Delayed Memory	6.00	1.32
Prospective Memory Test	6.06[a]	2.14
BADS Zoo Map	2.33[a]	1.00
Executive Function Predictors		
Clox 1	13.28	1.46
Trails B (seconds)	72.54	27.28
D-KEFS Letter Fluency total	43.18	11.39
Neuropsychological Predictors		
Trails A (seconds)	30.18	8.35
D-KEFS Category Fluency total	44.82	7.81
BVMT-R Copy	11.67[b]	.83

Notes. Unless otherwise indicated, mean scores are raw scores. MAS = Memory Assessment Scale (Williams, 1991); BADS = Behavioral Assessment of the Dysexecutive Syndrome (Wilson et al., 1996); Clox 1 (Royall et al., 1998); Trails A and B (Reitan & Wolfson, 1985); D-KEFS = Delis-Kaplan Executive Functioning Scale (Delis et al., 2001); BVMT-R = Brief Visuospatial Memory Test-Revised (Benedict, 1997). Younger adults were not routinely given laboratory testing.

[a] Data available for 46 of 50 participants.

[b] Data available for 48 of 50 participants.

Table 6

Mean Summary Data for the Day Out Task for the Older Adult and Younger Adult Groups

	Older Adult			Younger Adult		
Task Measures	**Mean**	**SD**	**Range**	**Mean**	**SD**	**Range**
DOT Test Variables						
Overall Task						
Planning Time (sec)	40.15[a]	34.67	0–173	48.64[d]	40.35	0-207
Total Time (min) †	11.10	3.30	5-20	7.54	1.71	4-12
Total Accuracy†	11.96	1.73	9-16	10.80	1.84	8-15
Sequencing Score	3.80	.99	2-6	4.64	.90	3-6
Tasks Interweaved	4.86	1.28	2-7	4.64	.90	2-7
Number of tasks initiated	7.94	.24	7-8	7.94	.24	7-8
Number of tasks completed	7.30	.86	5-8	7.44	.81	5-8
Examiner Ratings						
Task Quality†	2.05[b]	.91	1-5	1.60[e]	.59	1-4
Goal Directedness†	2.22[e]	.98	1-5	1.54[c]	.66	1-4
Subtask Completion Scores						
Number of tasks complete/efficient	4.80	1.28	2-7	5.84	1.24	3-8
Number of tasks complete/inefficient†	2.50	1.36	0-5	1.60	1.11	0-4
Number of tasks incomplete/inaccurate†	.64	.85	0-3	.50	.81	0-3
Number of tasks never attempted†	.06	.24	0-1	.06	.24	0-1

Notes. See Table 2 for coding schema.

[a]Data available for 48 participants.

[b]Data available for 43 participants.

[c]Data available for 49 participants.

[d]Data available for 45 participants.

[e]Data available for 30 participants.

†Higher scores represent poorer DOT performance.

Table 7

Correlations between Day Out Task Measures with Demographics, Multitasking Predictors, Executive Function Predictors, and Neuropsychological Predictors for the Older Adult Group

Variables	Complete/ Inefficient†	Total Time†	Total Accuracy Score†	Sequencing Score
Demographics				
Age	.23	.08	.31*	−.19
Education	−.15	−.36*	−.24	.01
Multitasking Predictors				
MAS Prose Memory	−.14	−.15	−.03	−.17
Prospective Memory Test	−.23	.01	−.14	.38**
BADS Zoo Map	.02	−.20	−.10	.18
Executive Function Predictors				
Trails B†	.33*	.26	.28*	−.19
D-KEFS Letter Fluency total	−.38**	−.21	−.22	.26
Clox 1	.07	.18	−.04	.10
Neuropsychological Predictors				
BVMT-R Copy	−.03	.18	.07	−.08
Trails A†	.20	.29*	.06	−.05
D-KEFS Category Fluency	−.27	−.20	−.27	.05

Notes. Total correct raw score was used for all neuropsychological measures. MAS = Memory Assessment Scale; BADS = Behavioral Assessment of the Dysexecutive Syndrome; D-KEFS = Delis-Kaplan Executive Functioning Scale; BVMT-R = Brief Visuospatial Memory Test-Revised.

†Higher scores represent poorer performance.

* $p < .05$

** $p < .01$.

Table 8

Beta coefficients, Change in R^2 and R^2 values for the multitasking, executive and neuropsychological predictors of DOT performances for the older adult group. Age and education were entered in Block 1, results are presented for Model 2

Variables	Complete/ Inefficient†	Total Time†	Total Accuracy Score†	Sequencing Score
Multitasking Predictors				
Age	.26	.07	.35*	−.26
Education	−.21	−.33*	−.23	−.04
MAS Prose Memory	−.22	−.17	−.09	−.07
Prospective Memory Test	−.33*	−.13	−.19	.35*
BADS Zoo Map	.14	−.04	−.01	.09
Change in R^2	.14	.04	.04	.15
R^2	.21	.18	.19	.22
Executive Function Measures				
Age	.06	−.04	.26	−.10
Education	−.04	−.29*	−.24	−.05
Trails B†	.22	.25	.12	−.07
D-KEFS Letter Fluency total	−.30*	−.09	−.04	.22
Clox 1	.14	.25	−.05	.05
Change in R^2	.14	.08	.02	.06
R^2	.22	.22	.18	.09
Neuropsychological Measures				
Age	.25	−.07	.29	−.17
Education	−.12	−.33*	−.16	−.02
BVMT-R Copy	−.05	.16	.05	−.07
Trails A†	.01	.33*	−.05	−.01
D-KEFS Category Fluency	−.21	.02	−.17	.02
Change in R^2	.04	.11	.03	.01
R^2	.15	.25	.16	.04

Notes. Total correct raw score was used for all neuropsychological measures. MAS = Memory Assessment Scale; BADS = Behavioral Assessment of the Dysexecutive Syndrome; D-KEFS = Delis-Kaplan Executive Functioning Scale; BVMT-R = Brief Visuospatial Memory Test-Revised.

† Higher scores represent poorer performance.

* $p < .05$.