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Effects of Initial Planning on Task Execution Performance of Older Adults: A Naturalistic Assessment Paradigm

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Abstract

Objective: Planning, a higher order executive functioning ability important for accomplishing complex everyday tasks, can be differentiated into initial and concurrent (online) planning. In this study, initial plans were codified to assess their impact on task execution. Cognitive correlates of initial planning and task execution were also examined.

Method: One-hundred fifty-four community dwelling older adults completed a naturalistic task, called the Day Out Task (DOT), in either a planning or no planning condition. The DOT required participants to multitask and efficiently complete a series of eight subtasks, preparing for a hypothetical day out. Participants also completed a neuropsychological battery with the following cognitive constructs assessed: processing speed, cognitive flexibility, episodic memory, visuoconstructional abilities, and working memory and sequencing.

Results: There were no significant differences between the planning and no planning conditions in DOT execution accuracy, efficiency or duration. However, efficiency of the initial plan was a significant predictor of task execution efficiency and initial plans that contained a higher amount of Task Relevant Associations predicted a shorter duration of task execution after controlling for age, processing speed and episodic memory. Furthermore, initial plans that had more Task Relevant Associations and task executions that took less time were associated with better working memory and sequencing ability.

Discussion: Quality of the initial plan is important. Initial plans that organize task objectives in an efficient manner may lead to better task execution efficiency, while initial plans that demonstrate a detailed understanding of individual relational aspects of the tasks (i.e., higher rate of Task Relevant Associations) may result in faster task execution.

Keywords

Planning; initial; concurrent; naturalistic assessment; aging

The logistics of taking a vacation (e.g., hotel rentals, car rentals, daily itineraries, packing, financial management) can often be overwhelming. The ability to plan allows us to manage

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such challenges. Planning is considered a higher order executive functioning ability that assists individuals in accomplishing complex everyday tasks, including efficiently and accurately preparing for a vacation. Planning involves a multitude of cognitive components, including processing speed, cognitive flexibility, memory processes, visuoconstructional abilities, and working memory (Avila, de Paula, Bicalho, Moraes, Nicolato, Malloy-Diniz, Diniz, 2015; Burgess, Simons, Coates, & Channon, 2005; Craik & Bialystok, 2006; Diamond, 2013). Although age-related decrements in planning ability have been well-documented (Craik & Bialystok, 2006; Köstering, Leonhart, Stahl, Weiller, & Kaller, 2016; Köstering, Stahl, Leonhart, Weiller, & Kaller, 2014; Martin & Ewart, 1997), research in this area has typically focused on concurrent (online) planning and there is a dearth of research on planning that takes place prior to action, or initial planning activity. In this study, a naturalistic task was used to investigate the relationship between initial planning abilities and task execution performance in older adults.

Several models of planning have been proposed (for a review see Mumford, Schultz, and Van Doorn's, 2001). Mumford and colleagues (2002) conceptualized planning as consisting of three components: initial plan formulation, plan refinement, and plan execution. During initial plan formulation, the environment is examined for opportunities and resources, prior knowledge and experience are used to help form ideas, goals are developed, and potential contingencies and consequences are generated. These activities result in formation of a prototype, or initial plan, that provides a foundation used for forecasting potential conflicts and outcomes, generating alternative actions, organizing goals and time, developing back up plans, and generating ways of monitoring the plan for plan refinement. Finally, after the plan has been refined, the plan is executed and during this aspect of the model, online plan adjustment occurs as needed and the plan is further refined when opportunities arise.

A second model of planning, conceptualized by Morris and Ward (2005), differentiates planning behavior into two overarching classifications: initial planning and concurrent (online) planning. These authors define initial planning as "planning activity that takes place before overt problem-solving action takes place" and concurrent planning as "the planning activity that is initiated "online" after problem solving has commenced" (Morris & Ward, 2005, p.38). The initial plan formulation and refinement aspects of Mumford and colleagues' (2002) model corresponds with Morris and Ward's initial planning behavior, while the plan execution aspect illustrates concurrent planning behavior. It has also been hypothesized that as the complexity of a problem increases, planning behavior may shift from initial planning to concurrent planning behavior to reduce working memory load (Davies, 2013; Köstering et al., 2014).

Historically, much of the neuropsychological research on planning has not mirrored models of planning, treating this multi-faceted construct as unitary (Goel et al., 2013). This has led to variable findings in the literature as the different tasks being investigated may not only draw upon different aspects of planning but also require different cognitive processes for performance (Goel et al., 2013). For example, planning ability has been measured through neuropsychological tasks like the Clock Drawing Task (CDT; Shulman, Shedletsky, Silver, 1986), and the Tower of London (TOL; Shallice, 1982). The TOL requires a participant to move stimuli, one at a time, using the fewest amount of moves to match a goal-state.

Currently, it is unclear whether the TOL measures aspects of mental-preplanning or only online planning (Phillips, Wynn, McPherson, & Gilhooly, 2001) and what specific cognitive abilities are involved (Gilhooly, Wynn, Phillips, Logie, & Della Sala, 2002). Similarly, the CDT, which requires a person to draw an analog clock and set the hands to a specific time, lacks clarity on what aspects of planning and cognitive processes it measures. In addition, these tasks have been described as lacking ecological validity (de Paula, 2013; Phillips, Kliegel, & Martin, 2006) and would not likely capture a person's ability to plan a complex weekly schedule, medication routine, or an overnight trip.

Given the limitations of these laboratory-based tasks, more naturalistic tasks have been developed to assess planning. For example, The Multiple Errands Task (MET; Shallice & Burgess, 1991), is a complex task that involves having participants complete a list of objectives in a real shopping complex while following specific rules. An observer follows the participant, recording inefficiencies and errors in completion of the objectives. Shallice and Burgess (1991) found that patients with frontal lobe lesions performed significantly more poorly on the MET than healthy controls. Several updated and modified versions of the MET, which require cooking breakfast, planning routes through use of a map, or following rules while running errands, can be found in the planning research literature (Brown & Hux, 2016; Garden et al., 2001; Jovanovski, Zakzanis, Campbell, Erb, & Nussbaum, 2012; Kliegel, McDaniel, & Einstein, 2000; Manly, Hawkins, Evans, Woldt, & Robertson, 2002; Sanders & Schmitter-Edgecombe, 2012; Wilson, Alderman, Burgess, Emslie, & Evans, 2003). These tasks are favored over more traditional measures for their potential ability to better capture a person's planning in everyday life (Dawson, Reg, Anderson, Burgess, Cooper, Krpan, & Stuss, 2009). However, like traditional measures of planning, most of these naturalistic tasks do not incorporate a pre-planning period, thereby forcing concurrent planning behavior (Morris & Ward, 2005). Furthermore, if participants do not create an initial physical plan or use a think aloud method (Gilhooly, Phillips, Wynn, Logie, & Della Sala, 1999), measuring or assessing initial planning ability becomes difficult.

Several research studies have evaluated initial planning abilities by having participants create an initial physical plan prior to task execution (Jovanovski, Zakzanis, Campbell, Erb, & Nussbaum, 2012; Wilson, Alderman, Burgess, Emslie, & Evans, 2003; Sanders & Schmitter-Edgecombe, 2012). These studies typically do not apply detailed scoring procedures to examine the components of the physical plan. However, they have incorporated sequencing scores. For example, physical plans developed in the Multitasking in the City Test were evaluated based on a sequence score that reflected how logical the plan was in regard to judicious decision making and a spatial perspective of the tasks that needed to be completed in various locations (Jovanovski et al., 2012). Similarly, the Amap task assessed physical plans by generating measures of formulation accuracy, which was determined by amount of task parts included in the plan, and formulation efficiency, which was determined by lack of overlap in the number of times participants planned to visit certain locations (Sanders & Schmitter-Edgecombe, 2012).

Within the aging literature, few studies have examined planning abilities by incorporating a planning formulation phase prior to task execution (Sanders & Schmitter-Edgecombe, 2017; Sanders & Schmitter-Edgecombe, 2012). Sanders and Schmitter-Edgecombe (2012) found

that on both formulation and execution stages of a complex task completed in a naturalistic home environment (i.e., aMAP), older adults performed more poorly compared to younger adults on measures of pre-planning efficiency and accuracy. In addition, the authors allowed half the older and younger adult samples to use their developed planning aid during task execution. For each age group, they found no differences in task execution efficiency or accuracy between individuals that used their developed planning aid during task completion and those that did not. In fact, the improved task execution scores compared to task formulation scores for both groups were interpreted by the authors as suggesting that both groups were able to successfully update and adjust their initial plans concurrently during task execution. In a later study, comparing the performances of younger and older adults who created a plan prior to task execution with those who did not, Sanders and Schmitter-Edgecombe (2017) again found that older adults created less efficient and less accurate plans compared to younger adults. The older adults also executed the task less accurately and less efficiently compared to the younger adults. Of importance, for both groups, although initial planning did not improve task accuracy during the execution phase it did improve task efficiency.

In the present study, the impact of initial planning on task execution in a community dwelling older adult sample (age 50+) was evaluated. In addition, the impact that aspects of an initial plan (e.g., Task Relevant Associations) can have on task execution was examined. Participants completed the Day Out Task (DOT; Schmitter-Edgecombe, McAlister, Weakly, 2012), a naturalistic task that was completed in a campus apartment and requires individuals to prepare for a hypothetical day out. The DOT requires multitasking and interweaving of tasks in a judicious manner for efficient task completion. Participants were provided with a list of the eight task objectives. Half of the sample were required to develop an initial plan for five minutes prior to task execution. The other half of the participants executed the task with no initial planning period. Initial plans were codified to capture aspects of the plan, including Plan Efficiency, Task Relevant Associations, Amendment Ratio, and Visual Organization (see Coding Procedure section), that may impact task execution performance (i.e., accuracy, efficiency, and duration).

Based on previous literature which found that, when compared to no planning, formulating an initial plan impacted task execution efficiency but not execution accuracy (Sanders & Schmitter-Edgecombe, 2016), we hypothesized that participants in the planning condition will demonstrate better DOT task execution efficiency, but not accuracy. The literature has indicated that initial plans are rarely perfect and individuals typically update and adjust their plans as they execute them, or while concurrently planning (Mumford et al., 2001; Sanders & Schmitter-Edgecombe, 2012). However, if an individual's initial plan consists of a large number of associated components relevant to the task objectives and is sequenced in an efficient order, less online updating and adjusting should occur because a good quality plan should lend itself to improved task execution. We therefore also hypothesized that well-developed plans will predict shorter task execution duration, as having task objectives organized in a judicious manner will decrease the need to change the order during execution and decrease the amount of time needed on the task.

The second study aim was to define cognitive processes that are associated with initial plan formulation and with task execution. Specifically, processing speed, cognitive flexibility, temporal order memory, episodic memory, visuoconstructional ability, and working memory and sequencing variables will be examined as each has been implicated in everyday functioning and planning (Cahn-Weiner, Malloy, Boyle, Marran, & Salloway, 2000; Gold, 2012; Gross, Rebok, Willis, & Brandt, 2011; Thorton & Dumke, 2005). Additionally, these cognitive variables have been found to decline with age (Andrés & der Linden, 2000; Bugg et al., 2006; Harado, Natelson, & Triebel, 2013; Salthouse, 2010; Salthouse, 2012; Wasylyshyn, Verhaeghen, & Sliwinski, 2011). Prior research has typically focused on the cognitive correlates of concurrent planning ability. This exploratory analysis will add to the literature on cognitive correlates related to initial planning abilities in older adults.

Method

Participants

Participants were volunteer community dwelling older adults, age 50+, who were recruited through health and wellness fairs, physician referrals, and advertisements. Participants were recruited as part of a larger study (N = 347) examining the relationship between everyday functioning and cognition across the healthy and pathological aging continuum that took place between 2013 and 2017 at Washington State University (WSU). Participants were initially screened with a medical interview and the telephone interview for cognitive status (TICS). If the participants had a TICS score in the dementia range (<27) or if the participant was unable to give informed consent, they were excluded from study participation.

Standardized neuropsychological testing was used to determine cognitive status. Exclusion criteria for the present study included age younger than 50, a history of neurological insult such as stroke, traumatic brain injury, tumors, brain surgery, Parkinson's disease, and other medical conditions that could potentially influence cognitive functioning. Furthermore, to be classified as a healthy older adult (HOA), participants could not meet criteria for MCI based on Petersen and colleagues' criteria (Petersen et al., 2001; Petersen & Morris, 2005). After applying these exclusion criteria, there were 164 eligible participants. After removal of participants who did not complete the DOT task or did not have a legible plan that could be coded, the final sample consisted of 78 participants in the planning condition and 76 participants in the no planning condition. As seen in Table 1, participants in the planning and no planning conditions did not differ significantly in demographics or cognitive testing performance.

Measures

Day Out Task (DOT; Schmitter-Edgecombe et al., 2012).—Participants completed a naturalistic task that required them to prepare for a hypothetical day out, multitasking and interweaving eight subtasks. Some examples of the subtasks include packing a picnic basket full of ingredients needed to make dinner at a friend's house, microwaving a heating pad for a hypothetical bus ride, and gathering the amount of money needed for the bus ride (refer to Figure 1 for more details). This task was administered in an apartment on WSU's campus that contained cameras and sensors and required participants to travel between rooms.

including a kitchen, living room, dining room, and hallway. Administrators observed participants carry out this task in a separate room on video monitors.

Neuropsychological Battery.—Participants completed a battery of neuropsychological tests for diagnostic classification. Although not a pure measure of each cognitive construct, the following tests were used to analyze the following cognitive constructs for this study (see Table 2): Trail Making Test A and B (processing speed and cognitive flexibility, respectively), the Activity Memory Paradigm temporal order measurement (temporal order memory), Hooper Visual Organization Test (visuoconstructional abilities), and WAIS-IV Digit Span Sequencing (working memory and sequencing). These domains of cognition have been shown to be related to performances on naturalistic planning tasks (McAlister & Schmitter-Edgecombe; Sanders & Schmitter-Edgecombe, 2012; Shallice & Burgess, 1991).

Procedure

Participants who passed initial screening criteria engaged in two testing sessions, each lasting approximately three hours. The first session occurred in a lab environment and consisted of standardized neuropsychological tests. The second session, administered approximately one-week later, consisted of experimental measures of complex activities of daily living that were administered in an apartment located at WSU.

During the second session, participants were asked to execute the DOT in a way that felt natural and efficient by multitasking and interweaving the task objectives. All participants were read the DOT instructions and provided with a list of task objectives as seen in Figure 1. Half of the participants were then provided with a separate blank sheet of paper for constructing an initial plan and required to plan for five minutes (planning condition). The other half of participants were asked to execute the task after hearing the initial instructions (no planning condition). Once participants in the planning condition finished planning (i.e., after five minutes), they were asked to complete the DOT task. At the start of the task, participants were seated at a table in the dining room. Both groups had access to the list of the task objectives throughout (see Figure 1). Based on prior findings, which revealed no benefit from carrying a planning aid when completing a similar complex task that allowed for multi-tasking (Sanders & Schmitter-Edgecombe; 2012), the planning group did not have access to their plan during task execution. DOT task objectives are structured around eight main goal items that participants must retrieve from specific locations (e.g., “The bus map and schedule are located in the organizer on the dining room table” or “You will find a magazine on the coffee table”) to prepare for their hypothetical day out. Additional details, such as some type of time or order requirement are also included which influences sequencing and efficiency (e.g., “You will need to microwave the heating pad for three minutes” or “Just prior to leaving the house, you will need to pretend to take the motion sickness medication ‘Dramamine’”). Initial plans were collected and a coding scheme was developed so that initial plans could be compared to DOT task performances.

Coding Procedure and Initial Plan Structure

To develop the coding scheme for the initial task plans, approximately 15 plans were selected at random for a preliminary analysis. Coding rules were then developed for this

study based on common features of the plans and components that are important for successful execution of the task. The following were coded as the eight main goal items: bus map, change, heating pad, picnic basket, magazine, recipe ingredients, Dramamine, and “exit phrase”. The “exit phrase” consists of anything indicating leaving the house after all other tasks are completed (e.g., “*Head out of the front door* when finished” or “*Leave the house* after taking Dramamine”). The following were coded as the locations where the main goal items could be obtained: kitchen, living room, dining room, hallway closet, and front door. If a participant indicated that an item could be found in something typically located in a specific room, without mentioning that room, coders were instructed to classify the appropriate location (i.e., “Grab ingredients from fridge”, would have the coded location of “kitchen”). Other coded planning variables included: Visual Organization of Information, a ratio of amendments made to the initial plan (i.e., Amendment Ratio), Plan Efficiency, Units of Meaningful Information (used in the calculation of the ratio of amendments) and Task Relevant Associations (see Table 3). All initial plans were coded by two independent raters.

Performance measures on the DOT consisted of an accuracy score and an efficiency score for task execution (See Table 4). Prior studies have demonstrated high inter-rater reliability, which was assessed (McAlister & Schmitter-Edgecombe, 2012) through total discrepancies in scoring between two raters for the DOT accuracy total (agreement = 97.88%) and the DOT sequencing scores (agreement = 99.57%). Total duration of DOT execution was also recorded and defined as the time between when the participant initiated the first task of the DOT to when they exited the front door of the apartment to indicate they had finished the task.

Statistical Analysis

To assess inter-rater reliability for the four planning variables, intra class coefficient (ICC) estimates and their 95% confidence intervals were calculated using SPSS (version 24) and a two-way mixed effect absolute agreement model. Independent samples *t*-tests were conducted to assess for group differences in DOT performance between individuals who created an initial plan (i.e., planning condition) prior to DOT execution and those who did not (i.e., no planning condition).

For the planning group, Pearson correlations were conducted to examine the relationship between the planning variables (i.e., Plan Efficiency, Task Relevant Associations, Visual Organization, and Amendment Ratio) and the DOT execution variables (i.e., accuracy, efficiency, and total duration). Because participants were given five minutes to create an initial plan and participants did not keep their initial plan during task execution, both processing speed (Trails A) and episodic memory (MAS Delayed List Recall) were included as covariates in the correlational analyses. Age was also treated as a covariate due to its significant relationship with Task Relevant Associations ($r = -.24, p = .04$), Plan Efficiency ($r = -.26, p = .02$), DOT Execution Accuracy ($r = .28, p = .02$), and DOT Total Duration ($r = .33, p = .004$). As education did not correlate significantly with any of the DOT task planning or task execution variables (ranges of $r = -.10$ to $.15$), it was not included as a covariate. To improve power for the regression analyses, initial planning variables that did not correlate with DOT execution variables were excluded from the hierarchical regressions.

Separate hierarchical multiple regression analyses were performed for each DOT execution criterion variable controlling for age, processing speed (Trials A), and episodic memory (MAS) in block one and using as predictors the initial planning variables that correlated with DOT execution variables.

To examine plan adherence, supplemental analyses were conducted with a plan adherence variable, which represented a correlation between the order of subtasks included in an initial plan and order of subtask execution for each participant. For plans that did not include all eight subtasks, correlations were only computed for the number of tasks that were included in the initial plan (e.g., if an initial plan only had five subtasks, a correlation was computed using the first five subtasks of task execution). Plan adherence was then correlated with initial planning variables (controlling for age and processing speed) and task execution variables (controlling for age and episodic memory). Finally, to examine for cognitive correlates of initial planning and task execution, exploratory Pearson correlations were conducted with DOT planning and execution variables and measurements of cognitive flexibility, temporal order memory, visuoconstructional abilities, and working memory and sequencing after controlling for age and processing speed (for initial planning) and controlling for age and episodic memory (for task execution).

Results

Inter-rater Reliability.

Intra class coefficient (ICC) for the four planning variables were as follows: Task Relevant Associations, ICC = .97 (CI = .96 – .98); Plan Efficiency, ICC = .99 (CI = .98 – .99); Visual Organization, ICC = .98 (CI = .97–.99); and Amendment Ratio, ICC = .98 (CI = .97 – .99). These values are considered to indicate excellent inter-rater reliability (Koo & Lee, 2016).

Planning and No Planning Group Comparisons.

Initial analyses were conducted to examine for group differences between the planning and no planning conditions. Results for group comparisons, including effect sizes, are displayed in Table 5. Consistent with the hypotheses, independent samples *t*-tests revealed that the two conditions did not differ in DOT execution accuracy, $t = .13$, $p = .90$, $d = .02$. However, inconsistent with the hypotheses, the groups also did not differ in execution efficiency, $t = .84$, $p = .40$, $d = .14$, or total task duration, $t = -1.37$, $p = .17$, $d = .22$.

Impact of Initial Planning on DOT Execution.

The finding of no significant difference between planning conditions in DOT task execution variables, does not necessarily negate a potential influence of initial plan creation on DOT execution performance. For the planning condition, examination of relationships between planning and task execution revealed significant correlations between two of the four planning variables and DOT execution variables after controlling for age, processing speed (Trials A) and episodic memory (MAS Delayed List Recall). As seen in Table 6, Task Relevant Associations correlated significantly with DOT total duration, $r = -.27$, $p = .02$, suggesting that initial plans that contained more Task Relevant Associations were associated with faster DOT execution. Task Relevant Associations did not significantly correlate with

DOT execution accuracy or DOT execution efficiency. In contrast, Plan Efficiency correlated significantly with DOT execution efficiency, $r = .43$, $p < .001$, but not with DOT execution accuracy or DOT total duration (see Table 6). This finding indicates that more efficient initial plans were related to a more efficient DOT execution performance. There were no significant correlations between the Visual Organization or Amendment Ratio planning variables and the DOT execution variables (See Table 6).

Hierarchical Regression Analyses.

Hierarchical regression analyses were conducted with the DOT execution criterion variables (i.e., DOT execution accuracy, DOT execution efficiency, and total duration) regressed onto age, processing speed (Trails A) and episodic memory (MAS Delayed List Recall) in block one and Task Relevant Associations and Plan Efficiency in block two. To increase power and decrease variable overlap, Plan Organization and Amendment Ratio were excluded from the analyses due to a lack of relationship with the criterion variables. Although Task Relevant Associations and Plan Efficiency were moderately correlated, $r = .27$, $p = .02$, collinearity diagnostics revealed a tolerance value of .88 and a VIF of 1.14, indicating no problems with multicollinearity.

As seen in Table 7, for DOT execution accuracy, the initial planning variables of Plan Efficiency and Task Relevant Associations did not explain additional variance over and above age, processing speed, and episodic memory, $R^2 = .04$, which accounted for 18% of the variance, $F = 5.26$, $p = .01$. In the full model, processing speed was the only significant predictor of DOT execution accuracy, $\beta = .33$, $t = 2.52$, $p = .01$. For DOT Execution Efficiency, after controlling for age, processing speed and episodic memory in block one (only 1% of variance accounted for), Plan Efficiency and TRA's accounted for a significant amount of additional variance, $R^2 = .21$, $F = 9.65$, $p < .001$. Plan Efficiency, $\beta = .51$, $t = 4.38$, $p < .001$, emerged as the only significant predictor of efficiency of DOT execution. Task Relevant Associations and Plan Efficiency similarly accounted for a significant amount of variance over and above age and processing speed for DOT total duration, $R^2 = .09$, $F = 3.88$, $p = .03$. However, for DOT total duration, TRAs, $\beta = -0.23$, $t = -1.98$, $p = .05$, emerged as the only significant predictor of time to complete the DOT.

Supplemental Analyses with Plan Adherence.

Pearson correlation analyses were conducted to examine the relationship between adherence to a plan and initial planning variables after controlling for age and processing speed (Trails A). Correlational analyses revealed that higher plan adherence (range = $-0.82 - 1.00$, $M = .39$, $SD = .48$) was associated with better initial Plan Efficiency, $r = .44$, $p < .001$, and with a larger number of amendments, $r = .26$, $p = .02$. No significant relationships emerged between plan adherence and Task Relevant Associations or Visual Organization (r 's $< .12$). To examine for relationships between adherence to a plan and DOT task execution variables, correlations were conducted controlling for age and episodic memory (MAS Delayed List Recall). A significant relationship between plan adherence and DOT execution efficiency emerged, $r = .24$, $p = .04$. Plan adherence was not related to DOT accuracy, $r = .01$, or DOT total time, $r = .04$.

Exploratory Correlation Analyses.

Exploratory Pearson correlation analyses (Table 8) were conducted to examine for relationships between cognitive correlates of initial planning variables after controlling for age and processing speed. Additionally, correlation analyses were conducted between task execution variables and cognitive variables controlling for age and episodic memory. There was a significant correlation between Task Relevant Associations and Digit Span Sequencing, $r = .26$, $p = .04$, a measure of working memory and sequencing ability. There were no other significant correlations between initial planning variables and cognitive variables. There was also a significant relationship between the total duration of task execution and Digit Span Sequencing $r = -0.24$, $p = .04$. Given that Task Relevant Associations and DOT Total Time (which were correlated) both correlated with Digit Span Sequencing, we conducted a partial correlation between these variables after controlling for age and Digit Span Sequencing; the significant relationship remained between number of Task Relevant Associations and DOT total execution time, $r = -.24$, $p = .04$.

Discussion

The primary objective of this study was to investigate the impact of initial planning on task execution performance in a community-dwelling older adult population, and to determine what aspects of an initial plan might lead to improved task execution. This research extends prior work by separating initial planning behavior from concurrent (online) planning behavior and by capturing aspects of initial planning ability, including sequencing efficiency and organizational components. Exploratory analyses further contribute information about potential cognitive correlates of initial planning ability to the literature.

A comparison between the planning and no planning conditions revealed no differences in DOT task execution accuracy, task execution efficiency, or total time on task. Using the aMAP task, Sanders and Schmitter-Edgecombe (2016) similarly found that initial planning did not impact task execution accuracy; however, initial planning did improve task efficiency in their study of community-dwelling older adults. In the current study, performance between the two conditions may not have differed because both conditions were provided with the same “to do list” that detailed the multiple task objectives. Since individuals in the initial planning condition did not have their initial plans to follow during the execution phase, they could have followed the “to do list”, mirroring the performance of the no planning condition. However, since participants are to multi-task and complete the subtasks in the most efficient way possible, simply following the order of the list would have led to a larger number of task sequencing errors than occurred, indicating an opportunity for either initial and/or concurrent planning to improve performance.

Another factor to consider is the impact of problem complexity. Davies (2003) found that initial planning is likely only beneficial for moderately complex problems. As the complexity of a task increases, working memory becomes taxed, resulting in more concurrent planning because concurrent planning reduces working memory load. Köstering and colleagues (2014) also found increasing working memory demands to influence planning behavior in favor of a concurrent planning strategy. The DOT is likely a highly complex planning task as it involves eight subtasks that must be interweaved in a judicious

manner while the individual must multi-task and monitor their performance for successful completion. The complexity of the DOT could have resulted in individuals in the planning condition abandoning their initial plans in favor of a concurrent planning strategy, mimicking performance of the no planning condition.

Further analyses, however, revealed that initial plans did have some influence on DOT performance. Specifically, the quality of the initial plan, rather than the act of making a plan, appeared to impact task execution. We found that task performance was positively influenced by plans that were efficiently sequenced and plans that contained a higher number of task related components required for successful completion of the task.

After controlling for age, processing speed, and episodic memory, task execution efficiency but not accuracy was predicted by plans that were characterized as more efficient. These findings suggest that initial plans that organize task objectives in a judicious manner may require less updating or adjustment during task execution, resulting in more efficient execution. In support of this, when plan adherence was assessed, individuals were more likely to adhere to their initial plans when they were more efficient plans, and higher plan adherence was associated with better task execution efficiency but not accuracy. Sanders and Schmitter-Edgecombe (2017) also found that initial planning improved execution efficiency on a naturalistic task (i.e., aMAP) but not accuracy. The authors hypothesized that accuracy and efficiency are likely hierarchical in nature and that accurate execution is less dependent on initial planning than task efficiency. The authors explained that initial planning provides a “structured opportunity to plan ahead” (p. 14) to efficiently complete a task. In the current study, plan adherence was also related to a higher rate of amendments to the initial plan, suggesting that participants who made more corrections to their plan engaged in less updating during task execution.

Unlike Plan Efficiency, Task Relevant Associations were not significant predictors of either task execution accuracy or execution efficiency but emerged as a significant predictor of task duration after accounting for age, processing speed and episodic memory. Initial plans that contained a higher number of Task Relevant Associations led to faster DOT completion times. Having a higher number of Task Relevant Associations may indicate that the participant had a detailed understanding of all aspects of the tasks (i.e., what item they needed to find, where the item was located, what should be done with the item), decreasing the amount of time needed for online planning and resulting in faster task execution. It appears that having a detailed understanding of the relationship between task components is more important for decreasing task duration than having task objectives organized in a judicious manner when a created plan is unavailable. Having a detailed understanding of each task may allow a person to more quickly execute task subcomponents, which could lead to a decrease in execution time. Although Task Relevant Associations only demonstrated a relationship with time in this study, a prior study with individuals with executive functioning deficits due to an acquired brain injury found a positive correlation between number of plan units, defined as “the smallest piece of information that could be asserted independently and judged true or false” (p. 195), and the number of tasks accurately executed (Brown & Hux, 2016). Together these findings suggest that a detailed

understanding of task components has the potential to positively impact accuracy as well as time.

In individuals with MCI, Sanders and Schmitter-Edgecombe (2014) found that more accurate and efficient plans led to better route adherence, which was related to better task execution efficiency on the aMAP task. However, this effect did not occur for their healthy older adult sample. The Sanders and Schmitter-Edgecombe (2014) study differed from the current study and the 2017 study as participants had access to their initial plans during task execution. We found that the older community-dwelling participants in the current study were more likely to adhere to their initial plan if it was an efficient plan and if they had made more amendments to it (possibly indicating that they may have been more conscientious or put more effort into creating their initial plan). This suggests that less updating and concurrent planning may have been necessary during DOT execution when efficient and thoughtful initial plans were developed. Furthermore, better DOT execution efficiency was associated with higher plan adherence.

Exploratory analyses with initial planning variables revealed that more Task Relevant Associations were related to better working memory and sequencing ability as assessed by the digit span sequencing subtest of the WAIS-IV. It is likely that a greater working memory capacity allows individuals to hold all aspects of the various task components in their mind (i.e., what objects they need, where the objects are located, what they need to do with the object) so that they can include these significant details in their initial plan. Other studies within the planning literature have found links between measures of information included in plans and working memory ability. For example, Martin and Ewert (1997) found a positive relationship between plan quality (measured by number of items of information included in a plan) and working memory. Rose and colleagues (2015) similarly found that on a breakfast planning task, working memory was crucial for plan formation and efficient performance. Additionally, better working memory and sequencing ability was related to less time spent on task execution. This may indicate that being able to hold more task components online facilitates faster task completion because the participant spends less time trying to figure out those task components.

There are several limitations to this study that should be considered. Participants did not have their initial plans during task execution. Keeping their initial plans could have resulted in a different outcome. However, Sanders and Schmitter-Edgecombe (2012) did not find having access to the formulated planning aid to affect task execution in the aMAP, a task of similar complexity. That is, although participants in their study were allowed to use their planning aids, their performance did not differ from the control group that was not provided with their planning aid during task execution. The current study is also limited by the neuropsychological measures used for the analyses of cognitive correlates as the measures do not purely tap one cognitive construct. This study did not have follow up questions to assess how the participants executed the task and how their initial planning may have impacted task execution. These types of questions would have provided insight into whether or not the participants perceived that they needed to frequently update their initial plans and if so, why they needed to make these adjustments. Finally, although we demonstrated that quality of an initial plan impacts performance, there were no differences in the DOT task

performance metrics between the planning and no planning conditions. It is important to keep in mind that even though the DOT was designed to be as naturalistic as possible, it is bound by time constraints and other variables (e.g., task difficulty). Therefore, the DOT may not fully capture the impact that planning may have on task execution with everyday goals that are on a larger scale, such as running errands to multiple locations around town or goals that take several days to accomplish and must be performed in a specific order. A more significant impact of initial planning on task efficiency, accuracy and time may be seen for such larger scale everyday tasks. Future studies should assess the impact of initial planning when participants are allowed to keep their generated plans. Additionally, future studies should continue to identify ways to measure initial plan adherence, assessing how much an initial plan changes as participants execute a task or concurrently plans. Davies (2003) demonstrated that individuals may have preferences over what type of planning strategy (initial or concurrent) they use. Assessing mediating variables for preferred strategy use, such as personality or cognitive factors, may reveal what planning interventions (i.e., concurrent or initial planning interventions) may be more effective for poor planners.

This study introduced supplementary methods of analyzing initial plans as opposed to solely using a simple unit count or amount of time for plan construction as most studies have done in the past (Brown & Hux, 2016; Davies, 2003; Martin & Ewert, 1997). We found that, although there were no DOT performance differences between the no planning and planning conditions, the quality of the initial plan did impact task execution for the planning condition. For individuals in the planning condition, initial plans that had subtasks sequenced in a judicious manner (Plan Efficiency) were associated with more efficient DOT execution. Plans that had a higher number of relevant related components of subtask objectives needed for successful task completion (Task Relevant Associations) were associated with faster DOT execution. The current analyses also provided information about cognitive correlates related to initial planning and task execution. Specifically, more Task Relevant Associations and faster task execution were related to better working memory and sequencing ability, likely because better working memory ability allows for more information to be held on line when creating an initial plan and during task execution. Future research should focus on interventions that target initial planning ability in order to improve task execution efficiency and time on task, and possibly task accuracy.

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Participant ID _____ Experimenter ID _____ Date _____

Things to do List

Objective: Be at museum by 10:00 a.m. to meet a friend

Choose a magazine for the bus ride (coffee table)

Just prior to leaving house, pretend to take "Dramamine" medication (cupboard "A")

Gather ingredients for spaghetti sauce recipe (cupboard "A" and refrigerator)

Plan bus route; record total time for bus trip and cost of bus fare (dining room table organizer)

Bring picnic basket to front door

Microwave heating pad for 3 minutes (cupboard "B")

Get correct change for bus ride (dining room table box)

Pack everything into picnic basket (clothes closet)

Locate spaghetti sauce recipe in recipe book (cupboard "B")

Total time for bus trip one way: _____

Cost of bus fare one way: _____

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: The activities can be completed in any order. Please multi-task and interweave to complete the tasks in an efficient and natural way

Figure 1:
Day Out Task objectives sheet provided to participants

Table 1.

Participant Demographics.

	Planning Condition <i>n</i> = 78		No Planning Condition <i>n</i> = 76		Group Comparison	
	M	SD	M	SD	t or X²	d
Age	68	8.98	68	8.31	−0.44	.00
Education	16.56	2.45	16.87	2.33	1.37	.13
Gender (% Female)	75.6%	-	70%	-	.68	.07
Race/Ethnicity (% Caucasian)	94.6%	-	98.6%	-	3.95	.16
TICS total	35.53	2.34	35.49	2.26	−0.10	.02
Processing Speed (Trails A)	29.90	7.01	29.84	9.29	−0.04	.01
Episodic Memory (MAS delayed list recall)	11.52	.70	11.49	.79	−0.27	.04
Cognitive Flexibility (Trails B)	73.62	22.93	69.59	30.98	−0.92	.15
WM & Sequencing (DSS)	9.01	1.79	9.41	2.29	1.19	.02
TO Memory (AMP)	7.22	1.49	7.21	1.41	−0.04	.01
VC Ability (Hooper)	25.58	2.21	26.11	2.19	1.51	.24

Note. TICS = Telephone Interview for Cognitive Status, MAS = Memory Assessment Scale, DSS = Digit Span Sequencing, WM = Working Memory, TO = Temporal Order, AMP = Activity Memory Paradigm, VC = Visuoconstructional. See Table 2 for a description of tests for the cognitive variables.

Table 2:**Neuropsychological Measures**

Measure	Task Description	Cognitive Construct
Trail Making Test, Part A (Reitan & Wolfson, 1985)	Quickly drawing a line connecting numbers in ascending order. Time is used to assess speed of processing.	Processing speed
Trail Making Test, Part B (Reitan & Wolfson, 1985)	Quickly drawing a connecting line, switching between letters and numbers in ascending order. Time is used to assess cognitive flexibility.	Cognitive flexibility
Activity Memory Paradigm, Temporal Order Memory (Schmitter-Edgecombe, Woo, & Greeley, 2009)	Temporal order memory paradigm requiring participants to remember order of completion of 8 tasks. An absolute difference score between remembered order and actual order is used as a measurement for temporal order memory.	Temporal order memory
Hooper Visual Organization Test (Hooper, 1983)	Requires the participant to organize visual information, constructing an image in their mind. Amount of correctly name images is used as a measure of visuoconstructional ability.	Visuoconstructional ability
WAIS-IV Digit Span Sequencing (Wechsler, 2008)	Requires the participant to sequentially order increasing strings of numbers orally presented by the examiner. Number of correct responses is used to assess working memory and sequencing.	Working memory and sequencing
Memory Assessment Scales, Delayed List Recall (Williams, 1990)	Requires participant to recall a list of orally presented words after a delay. Number of words correctly recalled is used to assess episodic memory.	Episodic memory

Table 3:**Planning Measures**

Plan Variable	Definition
Units of Meaningful Information	Total count of the smallest unit of meaningful information. Units consisted of main goal items, locations, verbs, and time. This is not a direct word count (e.g., the location, "Front door", would count as one unit of information, not two). Connector words such as a, the, and, etc. were not included in the units of meaningful information count. The units of meaningful information variable was needed to create the amendment ratio (see below) and is not used as a predictor.
Visual Organization of Information	Total count of how participants visually grouped information together in their plans. If participants simply had a list, that would count as one "grouping" of information. If participants had hierarchies or groups of information spaced out in chunks in their plan, each "grouping" received one point.
Amendment Ratio	Total count of each unit of information a participant amended or each change that occurred in their plan (i.e., each time the participant crossed out/rewrote a component of the plan or reordered a sequence using arrows to indicate a change). This total figure was divided by the total Units of Meaningful Information.
Plan Efficiency	An efficiency score was developed based on the following criteria (range 0–6): 1) "Bus map" mentioned as first task 2) "Heating Pad" mentioned within first four tasks 3) "Picnic Basket" mentioned within first four tasks, 4) "Bus map" mentioned before "change" with the caveat that change must be mentioned within the task, 5) "Dramamine" mentioned either second to last or last, 6) "Exit phrase" is last task unless it is paired with "Dramamine" as the last items mentioned in the plan (e.g., "Leave the house after taking Dramamine").
Task Relevant Associations	A task relevant association score was based off of meaningful pairings between the MGI and important components needed for successful execution of the task such as where the item could be found (location), what needed to be done with the item (verb), and if there was a time component (i.e., microwave the heating pad for 15 minutes). Each two-way pairing received 1 point (e.g., "Take the Dramamine" = MGI + Verb = 1 point). Three-way pairings received an additional bonus point (e.g., "Get the picnic basket from the hallway closet" = MGI + Location + Verb = 4 points).

Table 4:**DOT Execution Measures**

Execution Variable	Definition
Accuracy Score	An overall accuracy score (range = 8–31) was developed from the sum of subtask completion scores. Each subtask received a score from 1 to 4. The participant received a 1 if the subtask was completed accurately and efficiently. If an inefficiency in subtask performance occurred (e.g. not gathering the picnic basket within the first four tasks), it was coded as a 2. Incomplete/Inaccurate subtask performances (e.g., failure to retrieve key ingredient for recipe) were coded as a 3 if the subtask was not attempted, it was coded as a 4 for each task for a maximum total of 4 points. Higher points indicated poorer accuracy.
Efficiency Score	An efficiency score (range = 0–6) was based off of the following sequencing criteria: 1) The heating pad started within the first four activities 2) The picnic basket retrieved within the first four activities 3) The cost of the bus ride was determined before retrieval of the change. 4) Recipe read before food items were retrieved, 5) The Dramamine pill taken near end of task before exit 6) Picnic basket with items carried to front door as one of last two activities.
Total Duration	Total time was recorded as the time from when a participant initiated a subtask of the DOT until they ended the task by heading to the front door of the apartment to indicate they were finished with task objectives.

Table 5.

Group Comparisons of Planning Conditions

Variable	<i>n</i>	<i>M</i>	<i>SD</i>	<i>t</i>	<i>p</i>	<i>d</i>
<u>DOT Execution Accuracy</u>						
No planning condition	76	11.82	2.94	.13	.90	.02
Planning condition	78	11.76	2.94			
<u>DOT Execution Efficiency</u>						
No planning condition	76	4.16	.98	.84	.40	.14
Planning condition	78	4.02	.97			
<u>DOT Total Duration</u>						
No planning condition	76	640.62	192.12	-1.37	.17	.22
Planning condition	78	690.63	256.76			

Note. DOT = Day Out Task. Higher values for execution accuracy and total duration represent worse performance. Higher values for execution efficiency represent better performance.

Table 6.

Pearson Intercorrelations Between Predictor and Criterion Variables for Planning Condition Controlling for Age, Processing Speed, and Episodic Memory

	1	2	3	4	5	6	7
Plan Variables							
1. TRA	--						
2. Plan Efficiency	.27 [*]	--					
3. Visual Organization	.30 ^{**}	.20	--				
4. Amendment Ratio	.11	.13	.13	--			
DOT Execution Variables							
5. Accuracy	.05	−0.20	−0.02	−0.05	--		
6. Efficiency	−0.03	.43 ^{**}	−0.08	−0.08	−0.29 ^{**}	--	
7. Total Duration	−.27 [*]	−0.22	−0.07	−0.02	−0.17	−0.03	--

Note. TRA = Task Relevant Associations and DOT = Day Out Task. Higher values for execution accuracy represent worse performance. Higher values for execution efficiency represent better performance. Processing speed as measure by Trails A and Episodic Memory as measured by Memory Assessment Scales, Delayed List Recall.

^{*}
p .05

^{**}
p .01

Table 7.

Summary of Hierarchical Regression Results for Initial Planning Variables and DOT Execution Variables Controlling for Age, Processing Speed, and Episodic Memory

Predictors	DOT Execution Variables		
	Accuracy	Efficiency	Total Duration
Model 1			
Age	.	−0.01	.26 *
Processing Speed	.37 **	−0.08	.11
Episodic Memory	−0.08	.003	−0.05
Total R^2	.18	.01	.12
F for Total R^2	5.26. **	.20	3.26 *
Model 2			
Age	.04	.02	.21
Processing Speed	.33 **	.01	.01
Episodic Memory	−0.07	−0.03	−0.02
TRAs	.10	−0.17	−0.23 *
Plan Efficiency	−0.22	.51 **	−0.16
Change in R^2	.04	.21 **	.09 *
F for Change in R^2	1.88	9.65 **	3.88 *
Total R^2	.22	.22	.20
F for Total R^2	3.98 **	4.01 **	3.66 **

Note. Standardized beta coefficients presented for predictors. Processing speed as measured by Trials A. Episodic memory as measured by Memory Assessment Scales, Delayed List Recall. TRA = Task Relevant Associations

*
 p .05

**
 p .01

Table 8.

Pearson Intercorrelations between Initial Planning and Task Execution Variables with Cognitive Variables

	Initial Plan Variables ^a				Task Execution Variables ^b		
	TRA	Plan Efficiency	Visual Organization	Amendment Ratio	DOT Accuracy	DOT Efficiency	DOT Total Time
Cognitive Flexibility (Trails B) ⁺	.15	.02	.02	−0.08	.11	−0.12	−0.05
Temporal Order Memory (AMP) ⁺	−0.06	−0.02	.03	.01	−0.14	.04	−0.14
Visuoconstructional (Hooper)	.20	.19	−0.13	.06	−0.12	.18	.003
WM & Sequencing (DSS)	.26 [*]	.16	.14	.07	−0.18	.16	−0.24 [*]

Note. TRA = Task Relevant Associations, DOT = Day Out Task, AMP = Activity Memory Paradigm, and DSS = Digit Span Sequencing. Higher values for TRA and Plan Efficiency represent better quality. Lower values for Trails A and Trails B represent better performance. Higher values for AMP, Hooper, and DSS represent better performance.

^a age and processing speed controlled

^b age and episodic memory controlled

^{*} $p < .05$

^{**} $p < .01, n = 76$

⁺ $n = 75$