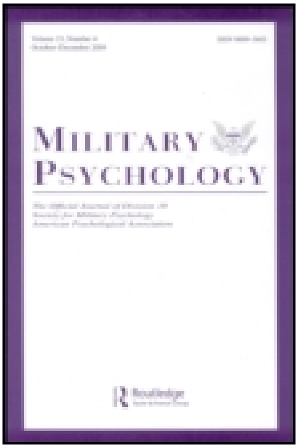

Military Psychology
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/hmlp20

The Relationship Between the ASVAB and Multitasking in Navy Sailors: A Process-Specific Approach

David Z. Hambrick [a], Tara A. Rench [a], Elizabeth M. Poposki [b], Emily S. Darowski [a], Donna Roland [c], Ronald M. Bearden [c], Frederick L. Oswald [d] & Randy Brou [c]

[a] Department of Psychology, Michigan State University, East Lansing, Michigan

[b] Department of Psychology, Indiana University-Purdue University Indianapolis, Indianapolis, Indiana

[c] Navy Personnel Research, Studies, and Technology, Memphis, Tennessee

[d] Department of Psychology, Rice University, Houston, Texas

Available online: 04 Jul 2011

To cite this article: David Z. Hambrick, Tara A. Rench, Elizabeth M. Poposki, Emily S. Darowski, Donna Roland, Ronald M. Bearden, Frederick L. Oswald & Randy Brou (2011): The Relationship Between the ASVAB and Multitasking in Navy Sailors: A Process-Specific Approach, Military Psychology, 23:4, 365-380

To link to this article: http://dx.doi.org/10.1080/08995605.2011.589323

MILITARY PSYCHOLOGY, 23:365–380, 2011

ISSN: 0899-5605 print / 1532-7876 online
DOI: 10.1080/08995605.2011.589323

The Relationship Between the ASVAB and Multitasking in Navy Sailors: A Process-Specific Approach

David Z. Hambrick and Tara A. Rench
Department of Psychology, Michigan State University, East Lansing, Michigan

Elizabeth M. Poposki
Department of Psychology, Indiana University-Purdue University Indianapolis, Indianapolis, Indiana

Emily S. Darowski
Department of Psychology, Michigan State University, East Lansing, Michigan

Donna Roland and Ronald M. Bearden
Navy Personnel Research, Studies, and Technology, Memphis, Tennessee

Frederick L. Oswald
Department of Psychology, Rice University, Houston, Texas

Randy Brou
Navy Personnel Research, Studies, and Technology, Memphis, Tennessee

This study investigated the relationship between ASVAB scores and multitasking performance in Navy Sailors. Sailors performed a "synthetic work" task designed to

---

The views expressed in this paper are those of the authors and do not reflect the official policy or position of the Department of Defense or NPRST. This research was approved by IRBs at NPRST and MSU.

Correspondence should be addressed to David Z. Hambrick, Department of Psychology, Michigan State University, East Lansing, MI 48824. E-mail: hambric3@msu.edu

simulate demands for multitasking common to many different jobs, as well as elementary cognitive tasks designed to measure two mental processes—the ability to update the contents of working memory (*memory updating*) and the ability to switch flexibly between tasks (*task switching*). Structural equation modeling revealed that a general factor of ASVAB subtest scores positively predicted multitasking. Furthermore, memory updating partially accounted for this relationship and added incrementally to the prediction of multitasking, above and beyond the ASVAB.

Scores on the Armed Services Vocational Aptitude Battery (ASVAB) have consistently been observed to positively predict performance in military jobs. For example, for each of a wide variety of military jobs (e.g., air-traffic controller, jet engine mechanic), Ree, Earles, and Teachout (1994) regressed measures of job performance onto a general factor of ASVAB subtest scores and found an average validity coefficient of .43 (see Ree & Earles, 1996, for a review). Furthermore, in a large-scale study of enlisted Army personnel ("Project A"), McHenry, Hough, Toquam, Hanson, and Ashworth (1990) found a correlation of .65 between overall performance on the ASVAB and "general soldiering performance."

Nevertheless, the ASVAB is obviously far from perfect as a predictor of military job performance. For example, if the ASVAB correlates about .40 with job performance, as Ree et al. (1994) observed, then the implication is that it accounts for about 16% of the variance in job performance (i.e., $.40^2 \times 100 = 16\%$), leaving about 84% of the variance unexplained—a portion of which is presumably explainable by factors not captured by the ASVAB. Furthermore, the question of what specific mental processes the ASVAB captures that might be important for job performance has received very little attention. Next, we describe a framework for addressing this question. We then present data from a study of multitasking in Navy sailors that illustrates how this framework can be used to better understand the nature of individual differences in the ASVAB.

Understanding Variation in the ASVAB

There has been considerable interest in recent years in linking individual differences in scores on standardized tests of cognitive ability and aptitude to the construct of *executive functioning*. Executive functioning is broadly defined as the ability to control thought and action in the service of accomplishing goals. For example, Lezak (1995) stated that "executive functions consist of those capacities that enable a person to engage successfully in independent, purposive, self-serving behavior" (p. 42), and Banich (2004) proposed that "Executive functions cover a variety of skills that allow one to organize behavior in a purposeful, coordinated manner, and to reflect on or analyze the success of the strategies employed" (p. 291).

These and other definitions of executive functioning are rather vague, and, perhaps as a consequence, there is no consensus about how to measure the construct. There are, however, a few tests that can be considered standard assessments in clinical and research settings. The *Wisconsin Card Sorting Test* (WCST) is an example. The test begins with presentation of a set of four cards across the top of a computer screen. Each card contains some number of objects of a particular color and shape. For example, Cards 1–4 might contain one red circle, two green stars, three blue squares, and three yellow crosses, respectively. A deck of cards appears at the bottom of the screen, and the subject's task is to sort the cards from the deck onto the four cards at the top of the screen according to a rule. Critically, the sorting rule is not explicitly stated; the subject must infer it using feedback provided after each trial. For example, if the rule is *color*, a correct sort is indicated through feedback if a card with two red stars is stacked on Card 1. After some number of correct sorts, the rule changes without warning, and the measure of "set-shifting" ability is the number of *perseverative errors*—the number of sorts made according to the previous, and now incorrect, rule.

Scores on the WCST and other tests of executive functioning correlate strongly with general intelligence (e.g., McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010). Furthermore, in a study of manufacturing plant employees, Higgins, Peterson, Pihl, and Lee (2007) found that a factor based on several tests of executive functioning—which they labeled *prefrontal cognitive ability* given the presumed dependence of executive tasks on the prefrontal cortex—correlated moderately ($r = .42$) with supervisor-rated job performance. However, the "task-impurity" problem is the observation that although neuropsychological tests such as the WCST may to some degree capture the factor they were designed to measure (e.g., set-shifting), they are complex and will certainly capture unintended factors, including other abilities (e.g., reasoning, memory) and nonability factors (e.g., motivation, fatigue), along with measurement error. Stated differently, no single executive task is "process-pure" (Burgess, 1997), and consequently, it is unclear whether correlations between measures of executive functioning such as the WCST and various outcome measures (e.g., job performance) are driven by the factor of interest, or by other, construct-irrelevant, factors.

The goal of an alternative approach to the measurement of executive functioning is to use experimental paradigms developed by cognitive psychologists to isolate *specific* mental processes hypothesized to be involved in executive control. Examples of such processes include the ability to select relevant information for processing while ignoring irrelevant information (*selective attention*), the ability to switch between tasks or goals or perform multiple tasks simultaneously (*task switching*), and the ability to update the contents of working memory, encoding relevant information and discarding irrelevant information (*memory updating*). This *process-specific* approach to executive functioning uses elementary cognitive tasks. Typically, the stimuli in these tasks are familiar to all test takers (e.g., digits, letters), and the instructions are very simple. For example, in a commonly administered test of task switching (see Logan, 2008, for other examples), digits are presented sequentially on a computer screen, and the subject is cued to classify each as odd or even, or lower or higher than five. After a run of trials of one type, a cue signals that the subject is to switch to the other judgment, and switching ability is defined as "switch cost"—the amount by which reaction time increases (slows) after the switch. As another example, memory updating is often measured with "n-back" tasks in which items (e.g., digits) are presented sequentially, and the subject indicates with a yes/no judgment whether each is the same as the item some number (often two) back in the sequence.

Recent studies provide evidence for empirically distinct executive functions. In a study by Miyake et al. (2000), subjects completed tasks similar to those just described, and structural equation modeling revealed evidence for moderately correlated, but statistically separable, *switching, updating*, and *inhibition* factors (see also Friedman et al., 2006; Friedman et al., 2008). Evidence from these studies further suggests that some executive functions are more strongly related to measures of cognitive ability than are others. For example, Friedman et al. (2006) found that a memory updating factor positively predicted fluid intelligence (Gf), as measured by tests of reasoning and problem solving, and crystallized intelligence (Gc), as measured by tests of vocabulary and information.

Present Study

Does the ASVAB capture individual differences in executive functions, and if so, might this help to explain its validity for job performance? To date, this question has not been investigated, but there is some reason to believe that the answer is yes. As mentioned, Friedman et al. (2006) found that memory updating positively predicted Gc, and Roberts et al. (2000) found that ASVAB subtests primarily loaded onto a Gc factor. By extension, then, one would predict a positive relationship between memory updating and ASVAB scores. The question of whether the ASVAB might capture other executive functions is open.

The aim of this study was to investigate the relationship between ASVAB scores and *multitasking* in a military sample. Defined as the requirement to perform two or more tasks simultaneously, or concurrently over a short period of time (Oswald, Hambrick, & Jones, 2007), multitasking is currently a central focus of discussions about the "changing world of work" and has been conceptualized as a core component of *adaptability* in the workplace. The reason to think that switching ability may be important for multitasking is obvious—by definition, multitasking involves some type of switching between tasks. We expected that the ASVAB-multitasking relationship would be strongest when multitasking required making many switches (i.e., under fast-paced conditions, compared with slow-paced conditions). An additional component of multitasking is updating working memory with the status of tasks in various stages of completion. More specifically, when the need to perform one task interrupts performing some other task, it is advantageous to be able to hold in mind information about the status of the interrupted task, so that it can be efficiently resumed at a later point in time. We therefore hypothesized that memory updating, along with task switching, would help to explain the relationship between ASVAB scores and multitasking.

To preview, Navy sailors performed tests of task switching, memory updating, and multitasking, and we obtained ASVAB scores from military personnel records. We then used structural equation modeling to test two hypotheses:

Hypothesis 1: A factor reflecting overall ASVAB performance would positively predict multitasking performance in a military sample.

Hypothesis 2: The relationship between this factor and multitasking performance would be mediated through task switching and memory updating.

We also performed analyses to investigate whether task switching and memory updating would add incrementally to the prediction of multitasking performance, above and beyond and contribution of the ASVAB.

METHOD

Participants

The participants were Navy sailors enrolled in Hospital Corpsman "A" School at the Great Lakes Naval Recruit Training Command. The 149 participants who contributed complete and usable data were predominantly male (80.5%) and ranged in age from 17 to 35 years ($M = 21.2$, $SD = 3.3$). Most participants (87.9%) reported 12 years of education ($M = 12.1$, $SD = 0.8$). Participants were enlisted sailors with rates ranging from E-3 to E-7; the percentage of participants at each level was E-3 (.7%), E-4 (2%), E-5 (28.2%), E-6 (20.8%), and E-7 (48.3%). There was a range of scores on the ASVAB (see Table 1), and percentile scores for the Armed Forces Qualifying Test (AFQT) ranged from 31 to 99 ($M = 59.5$, $SD = 17.6$). (The AFQT is a composite based on ASVAB subtest scores and is used to determine eligibility for enlistment in the U.S. military.[1])

[1]The AFQT score is computed as: 2(Verbal Expression) + Arithmetic Reasoning + Mechanical Knowledge (where Verbal Expression = Word Knowledge + Paragraph Comprehension). Prior to 2003, the minimum AFQT percentile score required for enlistment in the Navy was 31, and it is currently 35.

TABLE 1
Descriptive Statistics for ASVAB Subtest Percentile Scores

Subtest	*M*	*SD*	*Range*
General science	53.9	7.3	37–73
Word knowledge	51.4	6.8	34–72
Paragraph comprehension	53.6	5.8	34–68
Arithmetic reasoning	52.1	7.1	34–76
Mathematical knowledge	55.2	6.5	41–73
Numerical operations	56.8	6.7	35–69
Mechanical comprehension	53.1	9.1	27–79
Electronics information	52.8	8.2	35–77
Auto and shop information	49.2	8.4	32–80

Note. $N = 149$.

Procedure

Participants were recruited by the authors through contacts at the Great Lakes Naval Recruit Training Command. Potential participants were asked if they wished to participate in a research study concerning cognitive abilities; participants were tested in a classroom at the Great Lakes facility. Testing occurred in large groups of between 25 and 38 participants. Upon arrival at the study room, participants were seated and asked to read and sign an informed consent form. Participants completed the materials in a fixed order to avoid Subject × Order interactions.[2,3]

Measures

Memory updating. Memory updating was assessed via a computerized *digit updating* task. Each trial of this task consisted of the presentation of a digit

[2]Participants completed a number of other tests not relevant to the focus of the current research, including a reasoning test and a personality test. Participants also completed a third executive test ("distraction control"), which involved attempting to make judgments about visual stimuli in the presence of irrelevant information. Unfortunately, scores from this test were not interpretable, and we make no further mention of this task here.

[3]Of the 204 participants tested, 36 participants were missing SynWin scores due to an apparent equipment failure, and ASVAB scores were unavailable for nine participants. For another 11 participants, scores were negative for all SynWin blocks. The average AFQT score did not differ appreciably for these participants and for the other subjects in the sample (*M*s = 54.7 vs. 59.5), suggesting that these 11 participants had the ability to understand the instructions for the task but did not put forward a minimal amount of effort. Therefore, along with those with no SynWin or ASVAB scores, we omitted these 11 participants from all analyses, leaving a final sample of 149. Note also that Assembling Objects and Coding Speed scores were available for only a subset of the participants, and thus we excluded these subtests from analyses.

between 10 and 99 in the center of the screen. The participant's task was to press a key (left arrow or right arrow) to indicate (Yes or No) whether the digit was the same as the digit that appeared two screens prior (participants were to respond Yes on the first two trials). Following a practice block (45 trials), there were two test blocks with 45 trials each. Across blocks, 27 trials were targets (requiring a Yes response), and all other trials were mismatches (requiring a No response). We used overall accuracy (% correct) in the two blocks as our indicators of memory updating.

Task switching. Task switching was assessed via a computerized *digit switching* task. Each trial of the task consisted of the presentation of a digit between 10 and 99 in the center of the screen. The participant's task was to press a key (left arrow or right arrow) to indicate whether the digit was odd or even, or lower or higher than 50. In Non-Alternating blocks, all trials were of the same type (Odd-Even or Low-High), whereas in Alternating blocks, a trial of one type was followed by a trial of the other type, thus requiring the participant to switch the type of judgment from one trial to the next. (To illustrate, given the sequence 11, 52, 78, 33 in an Alternating block, the correct responses would have been Odd, High, Even, Low.) Following 15 practice trials (5 of each type), there were six test blocks with 60 trials per block; the order of blocks was: (1) Low-High, (2) Odd-Even, (3) Alternating, (4) Odd-Even, (5) Low-High, and (6) Alternating. We used average RT from the two Alternating blocks as our indicators of task switching.

Multitasking. Multitasking was assessed using the simulated multitasking environment called SynWin (Elsmore, 1994). As illustrated in Figure 1, this task includes four components. In *arithmetic* (upper right quadrant), the goal is to add numbers together, clicking "Done" to register the answer. In *memory search* (upper left quadrant), a list of letters is presented at the beginning of the session and then disappears; after the list disappears, probe letters are displayed periodically, and the goal is to judge whether each probe letter is from the set. In *auditory monitoring* (lower right quadrant), the goal is to respond to a high-pitched tone with a mouse click, and to ignore a low-pitched tone. Finally, in *visual monitoring* (lower left quadrant), a needle moves from right to left across a display resembling a fuel gauge, and the goal is to reset the needle before it reaches the red region. Participants performed six blocks of SynWin. Following a 1-minute practice block, there were three 3-minute "Baseline" blocks and then three 3-minute "Emergency" blocks. As summarized in Table 2, the pace of the tasks increased in moving from the Baseline to Emergency blocks, but the payoff scheme stayed the same. For each block, the measure of multitasking performance was the overall score, which was displayed in the center of the screen.

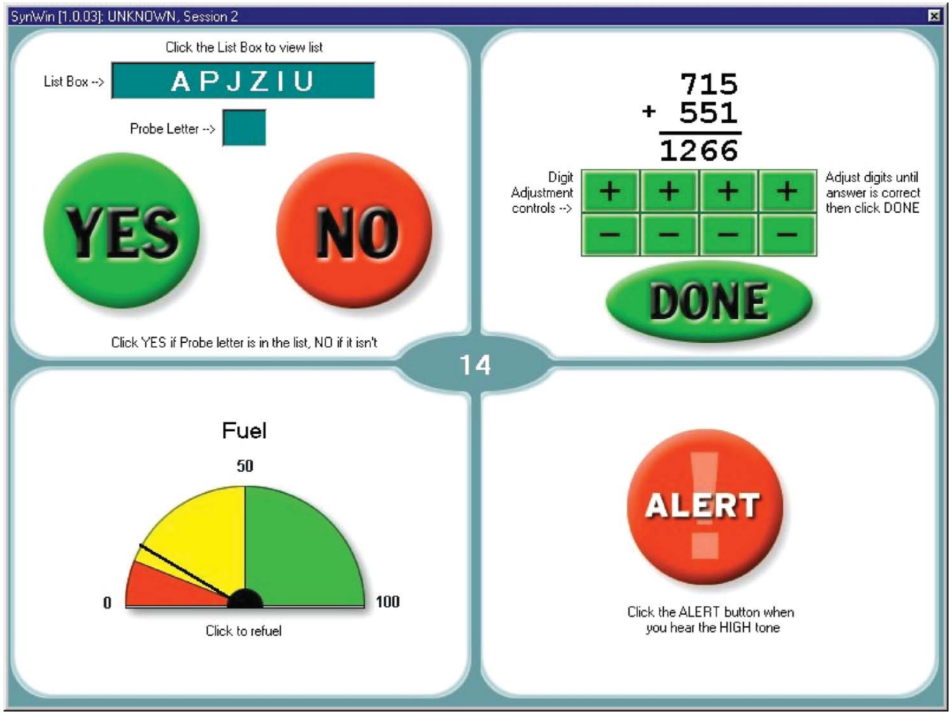

FIGURE 1 Screenshot from Elsmore's (1994) SynWin. (color figure available online)

TABLE 2
Parameters for SynWin in Baseline and Emergency Blocks

	Baseline			*Emergency*		
	Cor.	*Inc.*	*Rate*	*Cor.*	*Inc.*	*Rate*
Task						
Memory search	10	10	10	10	10	5
Arithmetic	20	10	—	20	10	—
Auditory monitoring	10	10	10	10	10	2
Visual monitoring	10	10	50	10	10	25

Note. Cor. = points awarded for correct responses. Inc. = points deducted for incorrect responses. Rate corresponds to (a) Memory Search: number of seconds between memory probes; (b) Auditory Monitoring: number of seconds between tones; (c) Visual Monitoring: number of seconds required for the needle to move across the gauge. The Arithmetic task is self-paced.

Power Analysis

With a sample size of 149, there was an acceptable level of statistical power (.80) to detect a correlation as small as .22, which Cohen (1988) defines as a "small" effect size.

RESULTS

Descriptive Statistics and Correlations

Executive functions. Accuracy for Digit Updating ($M = 69\%$, $SD = 20\%$) was in the expected range (Miyake et al., 2000), and the correlation between accuracy in Blocks 1 and 2 was very high ($r = .80$), indicating good reliability. Digit Switching also functioned as expected: RTs (msec) were nearly twice as fast in the Non-Alternating blocks ($M = 846.4$, $SD = 102.5$) as in the Alternating blocks ($M = 1597.5$, $SD = 323.9$), $t(148) = 32.97$ ($p < .01$), and accuracy was high in both blocks, Non-Alternating ($M = 97\%$, $SD = 3\%$) and Alternating ($M = 94\%$, $SD = 8\%$). The correlation between RT in the Alternating blocks was high ($r = .55$), indicating reasonably good reliability.[4]

[4]As another approach to obtaining a measure of task switching, we computed residual scores reflecting RT in an Alternating block after statistically controlling for RT in the Non-Alternating block and for accuracy in the Alternating block. Using this measure of task switching, the results are almost identical to those shown in Figure 2, and we opted to use the more interpretable average RT from the Alternating blocks as our indicators of task switching.

TABLE 3
Correlation Matrix for SynWin Scores in Baseline and Emergency Conditions

Variable	*1*	*2*	*3*	*4*	*5*	*6*
Baseline						
(1) Block 1	—					
(2) Block 2	.69	—				
(3) Block 3	.54	.71	—			
Emergency						
(4) Block 1	.54	.51	.52	—		
(5) Block 2	.51	.41	.44	.69	—	
(6) Block 3	.36	.37	.35	.65	.51	—

Note. All correlations are statistically significant ($p < .01$).

Multitasking. Table 3 displays correlations among the SynWin scores in the Baseline and Emergency conditions. Correlations were positive (avg. $r = .52$), but scores from each condition correlated more highly with each other (Baseline, avg. $r = .65$; Emergency, avg. $r = .62$) than with scores from the other condition (avg. $r = .45$), suggesting that there was a shift in factors underlying performance moving from the Baseline to Emergency blocks. Consistent with this impression, we entered the SynWin scores into a factor analysis (principal axis), and two factors emerged and were clearly interpretable as reflecting Emergency and Baseline performance. Coefficient alphas were .72 for the Baseline condition and .82 for the Emergency condition, indicating acceptable reliability.

ASVAB. We performed a hierarchical factor analysis to extract a general factor of ASVAB subtest scores (following a procedure described by Jensen & Weng, 1994). Two steps were involved. First, we entered the ASVAB variables into a factor analysis (principal axis) and saved scores for the three factors that had an eigenvalue greater than one. Following McHenry et al. (1990), we labeled these factors Technical, Verbal, and Quantitative (see Table 4). Next, we performed a factor analysis on these three factors. The first factor accounted for a large proportion of the variance (70.5%); we saved scores for this general factor (which we refer to hereafter as *ASVAB*) for use in subsequent analyses.[5]

Analytical Approach

The question for the next analyses was whether ASVAB would positively predict multitasking performance, as reflected in overall scores in SynWin, and whether

[5] Among other approaches, a general component from a set of variables can be obtained by entering the variables into a principal components analysis, or by simply averaging z scores for the variables (cf. Jensen & Weng, 1994). In our data set, general factors obtained using these approaches correlated very highly with the one actually used in our analyses (rs > .90).

TABLE 4
Exploratory Factor Analysis of ASVAB Subtest Scores

	Factor		
Subtest	*1*	*2*	*3*
General science	.11	**.68**	.05
Word knowledge	−.01	**.85**	−.05
Paragraph comprehension	−.12	**.57**	.08
Arithmetic reasoning	.17	.08	**.70**
Mathematical knowledge	−.23	.02	**.85**
Numerical operations	**.53**	−.18	**.35**
Mechanical comprehension	**.65**	.08	.24
Electronics information	**.56**	**.32**	−.08
Auto and shop information	**.94**	−.06	−.24
Eigenvalue	4.03	1.42	1.06
Proportion of variance	.45.	16	.12
Correlations			
1. Technical			—
2. Verbal		.66	—
3. Quantitative	.38	.38	—

Note. $N = 149$. Rotation procedure: Promax. Salient loadings (>.30) are bold and underlined.

this relationship would be mediated through executive functioning factors. We used structural equation modeling (SEM) to answer these questions. Mediation would be indicated by statistically significant effects of ASVAB on the executive factors, and in turn, statistically significant effects of the executive factors on multitasking (i.e., indirect effects), along with near zero effects of ASVAB on multitasking (i.e., direct effects). Partial mediation would be indicated by indirect effects, but still significant direct effects of ASVAB on multitasking.

Measurement Model

Two steps were involved in the SEM.[6] The first step was to perform confirmatory factor analyses to establish a measurement model for the constructs we assessed. The first model included Task Switching and Memory Updating factors, along with a Multitasking (MT) factor. Model fit was poor: $\chi^2(32) = 135.73$, CFI = .85,

[6]The χ^2 statistic reflects deviation between observed and reproduced covariance matrices, and thus, nonsignificant χ^2s are desirable. However, even with relatively small samples, χ^2 is sensitive to very slight deviations. The comparative fit index (CFI) and normed fit index (NFI) are less sensitive to sample size and reflect improvement in model fit over a baseline model in which covariances among the observed variables are assumed to be equal; values greater than .90 indicate good fit. The root-mean squared error of approximation (RMSEA) reflects the average squared difference between the observed and reproduced covariance matrices; values less than .08 indicate good fit (Kline, 2010).

NFI = .81, RMSEA = .15. The second model included Task Switching and Memory Updating, and separate Baseline MT and Emergency MT factors. Model fit was acceptable, $\chi^2(29) = 61.09$, CFI = .95, NFI = .92, RMSEA = .09, and improvement in fit over the first model was significant, $\Delta\chi^2(3) = 74.64$, $p < .01$.

Hypothesis Testing

The second step in the SEM was to test the hypotheses described earlier—that there would be a positive relationship between an ASVAB general factor and multitasking performance (Hypothesis 1), and that this relationship would be mediated through task switching and memory updating (Hypothesis 2). Results are shown in Figure 2, where it can be seen that ASVAB positively predicted Memory Updating (.23), which positively predicted Baseline MT (.24) and Emergency MT (.22). There were also significant direct effects of ASVAB on Baseline MT (.39) and Emergency MT (.25). Thus, Hypothesis 1 was supported, and Hypothesis 2 was partially supported in that the positive effect of ASVAB on the MT factors was partially mediated through Memory Updating. ASVAB was a nonsignificant predictor of Task Switching (–.06), which surprisingly was a nonsignificant predictor of the MT factors, Baseline (–.09) and Emergency (–.13). Total percentage of variance accounted for by the predictor variables was 27% for Baseline MT and 16% for Emergency MT. Model fit was acceptable, $\chi^2(36) = 66.22$, CFI = .96, NFI = .91, RMSEA = .08.

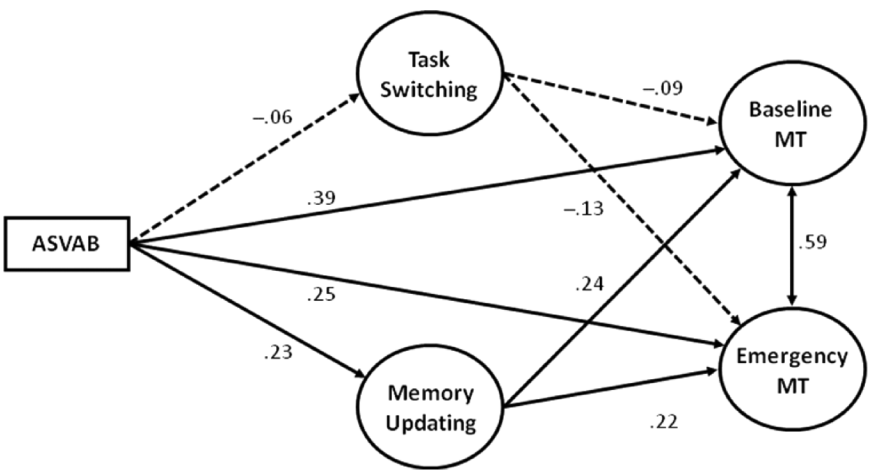

FIGURE 2 Structural equation model predicting multitasking performance. Solid paths are statistically significant ($p < .05$).

Incremental validity. To test for incremental validity, we performed a series of nested model comparisons that allowed for a formal statistical test of model differences. Task Switching accounted for essentially no variance in multitasking performance, as setting paths from Task Switching to the MT factors to zero had almost no impact on model fit (χ^2 change), and percentage of variance accounted for dropped negligibly (<1.5%) for both Baseline MT and Emergency MT. By contrast, there was a significant loss of overall model fit after setting to zero the paths from Memory Updating to Baseline MT and Emergency MT, $\Delta\chi^2(2) = 9.11$ ($p < .05$), and percentage of variance accounted for dropped from 27% to 22% ($\Delta R^2 = 5\%$) for Baseline MT and from 17% to 12% ($\Delta R^2 = 5\%$) for Emergency MT. Thus, Memory Updating added substantially to the prediction of multitasking, above and beyond ASVAB.

DISCUSSION

The ASVAB has been used to make personnel selection and classification decisions for millions of individuals. However, the question of what specific mental processes the ASVAB might capture has received little attention. We approached this question using a theory-driven, process-specific approach. In a sample of Navy sailors, we investigated relationships between a general factor of ASVAB subtest scores and measures of two executive functions—the ability to update the contents of working memory (memory updating) and the ability to switch between tasks (task switching). The two questions we sought to address were whether these executive functions would help to explain the relationship between ASVAB and multitasking, as measured by a synthetic work task, and whether they would add to the prediction of multitasking, above and beyond ASVAB.

We found evidence that ASVAB did in fact positively predict multitasking performance, and that memory updating helped to explain this relationship. Furthermore, memory updating added substantially to the prediction of multitasking (approximately 5%). This evidence is consistent with evidence suggesting that the ability to regulate the contents of working memory is an important determinant of success in complex cognitive tasks (e.g., Friedman et al., 2006; Hull, Martin, Beier, Lane, & Hamilton, 2008), and with results of a previous study in which it was found that measures of working memory capacity positively predicted multitasking performance (Hambrick, Oswald, Darowski, Rench, & Brou, 2010). Surprisingly, our measure of task switching did not predict multitasking. It is possible that we used the wrong measure of task switching. However, the type of task that we used is standard in the literature on executive functioning. Another possibility is that the type of task switching ability that we measured comes into play only in situations that require very rapid and continuous alternating between tasks (even more rapid than those simulated in our "emergency" condition).

We also found that there were direct effects of ASVAB on multitasking (see Figure 2). This finding indicates that there are other factors that need to be taken into account to fully explain the relationship between ASVAB and multitasking. The ability to inhibit dominant or automatic responses may be one such factor. For example, although most people have a strong tendency to answer a phone as soon as it rings, it may be advantageous to answer on a later ring, or even to not answer at all, when in the middle of a task such as composing an e-mail. Similarly, in SynWin, when a tone occurs in the auditory monitoring task, there is no need to respond immediately; the only requirement for avoiding a penalty is to respond before the next tone, and the intervening seconds can be used to complete a task already underway (e.g., arithmetic). Another factor that may be important is *selective attention*, which has also been referred to as *distraction control*—the ability to direct attention toward relevant information and away from irrelevant information (Darowski, Helder, Zacks, Hasher, & Hambrick, 2008). Selective attention may be important in multitasking when it is necessary to focus on and complete one task while ignoring other tasks.

Contributions, Limitations, and Future Directions

The present study represents one of the first attempts to assess individual differences in executive functions within a military sample, and to evaluate measures of executive functions as predictors of complex task performance. From a theoretical perspective, the results increase understanding of what the ASVAB captures that influences complex task performance, especially multitasking. That is, a measure designed to capture the ability to update the contents of working memory helped to explain the positive relationship between a general factor of ASVAB subtest scores and multitasking. The results are also potentially informative about the nature of individual differences in general intelligence (*g*). Specifically, although the ASVAB was not designed to measure *g*, scores on the test do correlate very highly with scores on widely administered tests of intelligence, and especially tests of verbal abilities and knowledge (i.e., crystallized intelligence; Roberts et al., 2000). Our finding of a positive relationship between ASVAB scores and a measure of working memory (i.e., memory updating) therefore provides further evidence to suggest that working memory processes underlie individual differences in general intelligence (e.g., Kane et al., 2004; Kyllonen & Christal, 1990).

We also believe our results are important from a practical perspective. Specifically, because we found that a measure assumed to reflect an important process of the working memory system showed incremental validity over the ASVAB for predicting multitasking performance (i.e., encoding relevant information and discarding irrelevant information), we believe that working memory measures could prove to be a useful supplement to the ASVAB for the purposes of job classification into military occupations that require higher or lower levels of multitasking. Working memory measures could also be useful within occupations for diagnostic purposes; that is, these measures could be used to identify individuals who might benefit from greater training in multitasking activities. Using military samples, a goal for future research is to evaluate the validity of memory updating and other executive functions for proficiency in specific tasks (e.g., decision making in air-traffic control), as well as for performance measures reflecting day-to-day work behavior (e.g., supervisory ratings).

We acknowledge two limitations of this study. First, due to strictly limited time for testing, we were only able to administer a small number of tests in this study, including a single test for each executive function. Thus, a goal for future research is to obtain multiple measures of each executive function so that we can model the data at the level of latent variables, which are closer to the theoretical constructs of interest. Second, the validity of SynWin for job performance is unknown, and this task does not resemble any particular military job. Thus, another goal for future research is to evaluate the validity of SynWin against realistic military tasks (e.g., air-traffic control).

ACKNOWLEDGMENTS

We thank Hubert Chen and Andy Jones for their comments to this paper. This research was supported by a grant from the Navy Personnel Research, Studies, and Technology contract number DAAD19-02-D-0001.

REFERENCES

Banich, M. T. (2004). Cognitive neuroscience and neuropsychology (2nd ed.). Boston, MA: Houghton Mifflin.

Burgess, P. W. (1997). Theory and methodology in executive function research. In P. Rabbitt (Ed.), *Methodology of frontal and executive function* (pp. 81–106). Hove, England: Psychology Press.

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Darowski, E. S., Helder, E. L., Zacks, R. T., Hasher, L., & Hambrick, D. Z. (2008). Age-related differences in cognition: The role of distraction control. *Neuropsychology*, *22*, 638–644. doi:10.1037/0894-4105.22.5.638

Elsmore, T. F. (1994). Synwork 1: A PC-based tool for assessment of performance in a simulated work environment. *Behavior Research Methods, Instruments and Computers*, *26*, 421–426. doi:10.3758/BF03204659

Friedman, N. P., Miyake, A., Corley, R. P., Young, S. E., DeFries, J. C., & Hewitt, J. K. (2006). Not all executive functions are related to intelligence. *Psychological Science*, *17*, 172–179. doi:10.1111/j.1467-9280.2006.01681.x

Friedman, N. P., Miyake, A., Young, S. E., DeFries, J. C., Corley, R. P., & Hewitt, J. K. (2008). Individual differences in executive functions are almost entirely genetic in origin. *Journal of Experimental Psychology: General*, *137*, 201–225. doi:10.1037/0096-3445.137.2.201

Hambrick, D. Z., Oswald, F. L., Darowski, E., Rench, T., & Brou, R. (2010). Predictors of multitasking performance in a synthetic work paradigm. *Applied Cognitive Psychology*, *24*, 1149–1167. doi:10.1002/acp.1624

Higgins, D. M., Peterson, J. B., Pihl, R. O., & Lee, A.G.M. (2007). Prefrontal cognitive ability, intelligence, big five personality, and the prediction of advanced academic and workplace performance. *Journal of Personality and Social Psychology*, *93*, 298–319. doi:10.1037/0022-3514.93.2.298

Hull, R., Martin, R. C., Beier, M. E., Lane, D., & Hamilton, A. C. (2008). Executive function in older adults: A structural equation modeling approach. *Neuropsychology*, *22*, 508–522. doi:10.1037/0894-4105.22.4.508

Jensen, A. R., & Weng, L. (1994). What is good *g*? *Intelligence*, *18*, 231–258. doi:10.1016/0160–2896(94)90029–9

Kane, M. J., Hambrick, D. Z., Tuholski, S. W., Wilhelm, O., Payne, T. W., & Engle, R. W. (2004). The generality of working memory capacity: A latent-variable approach to verbal and visuospatial memory span and reasoning. *Journal of Experimental Psychology: General*, *133*, 189–217. doi:10.1037/0096-3445.133.2.189

Kline, R. B. (2010). *Principles and practice of structural equation modeling* (3rd ed.). New York, NY: Guilford Press.

Kyllonen, P. C., & Christal, R. E. (1990). Reasoning ability is (little more than) working-memory capacity?! *Intelligence*, *14*, 389–433. doi:10.1016/S0160-2896(05)80012-1

Lezak, M. D. (1995). *Neuropsychological assessment* (3rd ed.). New York, NY: Oxford University Press.

Logan, G. D. (2008). The role of memory in the control of action. In E. Morsella, J. A. Bargh, & P. M. Gollwitzer (Eds.), *Oxford handbook of human action* (pp. 427–441). New York, NY: Oxford University Press.

McCabe, D. P., Roediger, H. L., McDaniel, M. A., Balota, D. A., & Hambrick, D. Z. (2010). The relationship between working memory capacity, frontal lobe functioning, and general fluid intelligence: An adult lifespan study. *Neuropsychology*, *22*, 638–644. doi:10.1037/a0017619

McHenry, J. J., Hough, L. M., Toquam, J. L., Hanson, M. A., & Ashworth, S. (1990). Project A validity results: The relationship between predictor and criterion domains. *Personnel Psychology*, *43*, 335–354. doi:10.1111/j.1744-6570.1990.tb01562.x

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, *41*, 49–100. doi:10.1006/cogp.1999.0734

Oswald, F. L., Hambrick, D. Z., & Jones, L. A. (2007). Keeping all the plates spinning: Understanding and predicting multitasking performance. In D. H. Jonassen (Ed.), *Learning to solve complex scientific problems* (pp. 77–97). Mahwah, NJ: Lawrence Erlbaum.

Ree, M. J., & Earles, J. A. (1996). Predicting occupational criteria: Not much more than *g*. In I. Dennis & P. Tapsfield (Eds.), *Human abilities: Their nature and measurement* (pp. 151–165). Mahwah, NJ: Lawrence Erlbaum.

Ree, M. J., Earles, J. A., & Teachout, M. S. (1994). Predicting job performance: Not much more than g. *Journal of Applied Psychology*, *79*, 518–524. doi:10.1037/0021-9010.79.4.518

Roberts, R. D., Goff, G. N., Anjoul, F., Kyllonen, P. C., Pallier, G., & Stankov, L. (2000). The Armed Services Vocational Aptitude Battery (ASVAB): Little more than acculturated learning (Gc)!? *Learning and Individual Differences*, *12*, 81–103. doi:10.1016/S1041-6080(00)00035-2