# Individual Differences in Multitasking Ability and Adaptability

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Multitasking has become increasingly prevalent in people's personal and professional lives. Considerable research has attempted to identify the characteristics of people (i.e., individual differences) that predict multitasking ability, and more importantly, the ability to rapidly cope with changing task demands (*adaptability*). This question was assessed in an experiment wherein participants first completed a battery of individual differences tests of cognitive abilities, then multitasked in a flight simulator in which task difficulty was incrementally increased via three experimental manipulations. The results indicated that general aptitude and working memory predicted general multitasking ability, but spatial ability was the dominant factor for adapting to increasing difficulty in this flight simulator task. We conclude by discussing the implications and applied aspects of these findings.

Multitasking has become a common practice in today's connected world. Not only do most professions require some level of multitasking (Bühner, König, Pick, & Krumm, 2006), but certain individuals exhibit a preference for multitasking[1] versus completing a single task at a time (e.g., Slocombe & Bluedorn, 1999; Poposki, Oswald, & Brou, 2009). It is well known that multitasking incurs drastic reductions in performance for most people (Monsell, 2003). It is also evident that these reductions are not the same for everyone. Hence, discriminating the individuals who can cope with multiple task demands and maintain consistent performance from their less-adaptable counterparts has significant applied implications.

For decades, researchers have attempted to identify the various states and individual difference traits associated with superior multitasking performance. For example, characteristics such as anxiety (Oswald, Hambrick, & Jones, 2007; Poposki, Oswald, & Chen, 2008), perceptual speed (Oberlander, Hambrick, Oswald, & Jones, 2007), and motivation (Oswald, Hambrick, & Jones, 2007) have been linked to multitasking performance. The critical component of multitasking, however, appears to be various aspects of working memory and executive control (e.g., Bühner, König, Pick, & Krumm, 2006; Hambrick, Oswald, Darowski, Rench, & Brou, R. 2009; Oberlander, Hambrick, Oswald, & Jones, 2007; Rubinstein, Meyer, & Evans, 2001).

Although considerable research has identified various individual differences measures (IDMs) related to multitasking performance, the question of which cognitive abilities predict *adaptability* remains open. That is, who are the individuals who can adapt when tasks become more difficult? This is a crucial question because it is important to realize that an aptitude in one area might explain general multitasking ability, yet not affect the change in performance as the task difficulty increases. For example working memory might be predictive of multitasking performance in a flight simulator task under normal operating conditions, but high perceptual acumen might be more relevant when task difficulty increases.

Considering the growing importance of multitasking in personal and professional spheres, identifying the cognitive abilities needed for adapting to changing circumstances is critical. Thus, the aim of the current study was to identify cognitive abilities related to adaptability in a multitasking scenario and to determine if these

[1] For the purposes of this paper, multitasking is defined not only as performing multiple tasks, but also switching from one task to another over short time spans (Oswald, Hambrick, Jones, & Ghumman, 2007).

faculties were the same as those necessary for superior multitasking in general.

To identify the cognitive abilities related to multitasking performance and adaptability, we collected measures of creativity, working memory, aptitude, and spatial ability. These measures were then correlated with performance on a difficult flight simulator task which required attending to four continuous tasks simultaneously.

In regards to general multitasking ability, we hypothesize that established predictors of multitasking performance (i.e., working memory) will be associated with higher performance. With respect to adaptivity, there are two hypotheses. First, the cognitive abilities required for superior multitasking performance are also necessary for adaptability. Alternatively, a second hypothesis states that adaptability requires faculties that are unrelated to overall multitasking performance. If the latter is the case, then identifying such abilities might represent a significant advance in the knowledge in this area.

## METHODS

### Participants

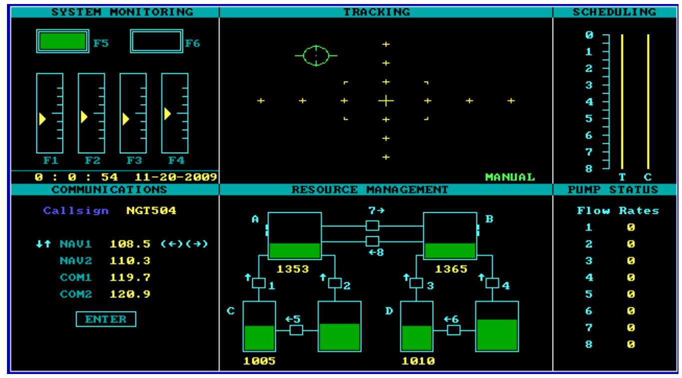
The sample was comprised of 32 undergraduate students from the University of Notre Dame and the University of Memphis.

### Multi-Attribute Task Battery

The Multi-Attribute Task Battery (MATB; Comstock & Arnegard, 1992) is a computerized flight simulator that requires users to simultaneously attend to four individual tasks: System Monitoring, Communications, Resource Management, and Tracking. The MATB interface is shown in Figure 1. Performance scores for the MATB were calculated as a product of the scores on the four individual tasks and were displayed to participants via a performance gauge (not shown in the figure).

*System Monitoring*. In the top-left quadrant of the screen, participants were asked to respond to feedback from lights and gauges. There were two lights at the top of the quadrant: a green light and a red light. Participants were instructed to press the `F5` key if the green light turned off and to press the `F6` key if the red light came on.

Figure 1. The MATB interface.




Beneath the two lights were four gauges, each associated with a corresponding key on the keyboard. Each gauge also had a yellow pointer that typically hovered around the center line. Participants were asked to press the corresponding key if any gauge's pointer exceeded one unit in either direction for the gauge's center line.

*Communications*. In the bottom-left quadrant, participants were given an identifying call sign (e.g., NGT504) and asked to follow audio instructions directed to their call sign while ignoring instructions from other call signs. Each message began with a six-digit call sign, followed by a command to change the digits in order to tune in to a particular radio frequency with the keyboard.

*Resource Management*. In the bottom-right quadrant, participants were asked to manage the fuel levels of two tanks by keeping the levels within a certain range indicated by tick marks on each tank. Because the fuel in these tanks decreased constantly, participants used the keyboard to transfer fuel from the supply and reservoir tanks.

*Tracking*. In the top-right quadrant, participants were asked to control a joystick in order to keep a moving reticle as close as possible to the center cross.

### Procedure

The experiment was divided into two phases that took approximately one hour each. The first phase was a battery of individual differences measures, whereas the second phase was the Multi-Attribute Task Battery.

*Individual differences measures*. Participants completed a battery of tests that measured a number of cognitive abilities. Participants self-reported their SAT Reasoning Test or American College Test

(ACT) score (in the absence of an SAT score, an ACT score was converted into an equivalent SAT score). All subsequent measures were administered via computer. These included measures of *creativity* (Remote Association Task; Topolinski & Strack, 2009), *scholastic aptitude* (SAT Reasoning Test), *working memory* (Comprehension Span; Waters & Caplan, 1996), and *spatial ability* (Mental Rotation Task; Shepard & Metzler, 1971).

*Multi-Attribute Task Battery*. Following the battery of individual differences measures, participants completed each of five phases in the MATB.

The first phase, Practice, consisted of practice sessions for each task individually. Subsequent phases had participants attend to all four tasks simultaneously. The second phase, Baseline (BL), had all four tasks at the low difficulty level. Participants did not receive performance feedback during Practice and Baseline, but did receive performance feedback in the other three phases. The third phase, Single Difficulty (SD), raised the difficulty level of Tracking to medium for one minute, while the others remained the same (easy). After one minute, the difficulty was lowered so that all four tasks were at the easiest difficulty again for one minute, then System Monitoring would increase to medium difficulty for one minute, and so forth, until this happened twice for each task. The fourth phase, Paired Difficulty (PD), raised the difficulty of the System Monitoring and Communications tasks together to medium, after which they reverted back to easy. Finally, in the last phase, Difficulty Ramp-Up (RU), all four tasks were at the easiest difficulty for one minute, at medium difficulty for one minute, and at the hardest difficulty for one minute.

## RESULTS

We analyzed scores over the four individual conditions (Baseline, Single Difficulty, Paired Difficulty, and Ramp-Up) and correlated them with the IDMs. Occasional missing IDM values were replaced with a multiple imputation procedure (Little & Rubin, 1987). All scores greater than two standard deviations from the mean were considered outliers and were removed.

To assess multitasking ability, we correlated the five scores and five IDMs, which are displayed in Table 1. The major predictors of overall and individual MATB scores were the SAT and Comprehension Span, indicating that scholastic aptitude and working memory are critical for multitasking performance.

Table 1. Correlations between IDMs and MATB scores

| | BL | SD | PD | RU |
|---|---|---|---|---|
| Spatial Ability | -.28 | .15 | .09 | .21 |
| Aptitude | .33* | .48** | .47** | .25 |
| Creativity | -.17 | -.07 | .07 | -.08 |
| Working Memory | .28 | .57*** | .22 | .26 |

* $p < .10$, ** $p < .05$, *** $p < .01$
BL = Baseline; SD = Single Difficulty
PD = Paired Difficulty; RU = Difficulty Ramp-Up

In addition to overall multitasking ability, we also sought to identify which measures could identify an individual’s ability to adapt to new constraints. Using the Baseline condition as a control, we performed a partial correlation with IDMs and performance on the three experimental phases. In doing so, we can remove the variance explained by individuals’ general multitasking ability and directly assess how they adapted to the increased difficulty of the experimental phases. The results in Table 2 show that individuals with high spatial ability improved dramatically in the more difficult sections of the task. Additionally, working memory remained statistically significant for the Single Difficulty condition only, but aptitude was no longer a significant predictor of performance.

Table 2. Correlations between IDMs and MATB scores (Controlling for Baseline scores)

| | SD | PD | RU |
|---|---|---|---|
| Spatial Ability | **.64**** | **.51***** | **.54***** |
| Aptitude | .36 | .05 | .28 |
| Creativity | -.38 | -.15 | -.14 |
| Working Memory | .62** | .08 | .13 |

* $p < .10$, ** $p < .05$, *** $p < .01$
BL = Baseline; SD = Single Difficulty
PD = Paired Difficulty; RU = Difficulty Ramp-Up

Next, we assessed the combined effects of spatial and working memory abilities on adaptability. Accordingly, we performed three hierarchical multiple linear regressions on Single Difficulty, Paired Difficulty, and Difficulty Ramp-Up scores. Participants’ Baseline scores were entered first in order to control for individual differences in baseline performance (Step 1), followed by mental rotation and comprehension span scores together (Step 2). A significant Step 2 model would suggest that the individual differences variables explain additional variance above and beyond the baseline scores.

The Step 2 models for all three experimental phases were statistically significant ($p < .01$). For the Single Difficulty condition, the $R^2$ adj. for the final model was .63, which is consistent with a large effect. The beta weights were .31 for both mental rotation and comprehension span, and both were statistically significant predictors ($p < .03$).

In the Paired Difficulty and Difficulty Ramp-up conditions, working memory was not a statistically significant predictor in the final model ($p > .13$) whereas mental rotation was significant ($p < .04$). The $R^2$ adj. for the final model in the Paired Difficulty condition was .51, and the standardized beta weight for mental rotation was .34 ($p < .04$). The adjusted $R^2$ for the final model in Difficulty Ramp-Up was .43, and the standardized beta weight for mental rotation was .49 ($p < .01$). In general, these results indicate that spatial ability was more predictive of adaptability than working memory.

Finally, it is possible that the MATB might have an inherent bias towards spatial abilities, specifically in the tracking task. However, there was no correlation between spatial ability and performance on the tracking task in the baseline condition, $r(24) = -0.04$, $p > .85$, indicating there was no spatial bias in the tracking task and that the improvement was due to qualities inherent in spatial ability and not the task itself.

## DISCUSSION

This paper sought to identify the cognitive abilities associated with multitasking performance and an individual's ability to adapt when the tasks became more difficult. We first predicted that working memory would be the strongest predictor of general multitasking performance. We then proposed two hypotheses for adaptability: the first suggested that abilities associated with general multitasking ability would predict adaptability, whereas the second proposed that adaptability is governed by a separate, distinct ability unrelated to general multitasking performance.

We addressed the first hypothesis by correlating our IDMs with scores on the four MATB conditions. Working memory was a significant predictor of multitasking ability, as expected, as was general aptitude. Creativity and spatial ability were not associated with performance on any of the conditions.

After identifying the abilities associated with general multitasking ability, we proceeded to analyze adaptability within the MATB task. We conducted partial correlations and hierarchical multiple linear regressions to account for performance in the Baseline condition.

The results of the analyses on adaptability showed that, while general aptitude is important for general multitasking ability, it is largely absent when assessing adaptability. Additionally, working memory was only relevant for Single Difficulty, the least difficult of the three adaptive conditions. Most importantly, however, spatial ability was a significant predictor for all three of the conditions with added difficulty. Thus, adaptivity when multitasking required cognitive abilities beyond those needed for superior performance in the task itself, supporting our second adaptability hypothesis.

We previously found in another study with a curve-drawing task, mental rotation (Morgan et al., in preparation) was also a predictor of adaptability in strategy shifting. It is reasonable to assume that the curve-drawing and MATB tasks have inherent spatial components; indeed, there is a relationship between spatial ability and multitasking performance in a spatial task (Colom, Contreras, Shih, & Santacreu, 2003). However, there was no relationship between spatial ability and baseline performance in either the curve-drawing or MATB tasks. Thus, the results provide evidence that spatial ability is predictive of the ability to adapt to changing task constraints when the task has a spatial component. Future research will address the issue of any spatial bias by using a multitasking environment with reduced spatial components.

Overall, these findings raise some important issues for multitasking and human-computer interaction. In many multitasking environments, the difficulty and cognitive load are not static, but can increase unexpectedly. Organizations selecting individuals for these types of tasks should be aware that standard multitasking IDMs (e.g., working memory) should not be the only criterion, but that other cognitive abilities (specifically spatial ability) play a role when the task constraints change.

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