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COGNITIVE INDIVIDUAL DIFFERENCES PREDICT STRATEGY SELECTION IN A FUTURE MEMORY TASK

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A Dissertation APPROVED FOR THE DEPARTMENT OF PSYCHOLOGY

BY

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Abstract

Two studies were conducted to determine whether cognitive individual differences predict strategy selection in a multitask scenarios. In Experiment 1, operation span, executive control capacity, and comfort with situational ambiguity were found to be significant predictors of strategy selection. In Experiment 2, comfort with situational ambiguity was found to be a significant predictor of strategy selection in a low workload condition. Under high workload conditions, operation span and executive control capacity were found to be significant predictors of strategy selection. Because individual differences act as mediators of strategy selection in multitasking, cognitive individual difference factors may prove to be useful tools in employee selection. Optimal performance in some positions (e.g., air traffic controller) may necessitate the use of specific strategies. Whether individuals are capable of using (or choose to use) particular strategies may be determined by examining their cognitive individual differences.

Cognitive Individual Differences Predict Strategy Selection in a Future Memory Task

Traditional memory research generally focuses on an individual's recall or recognition of information learned or experienced in the past. In contrast, research within the area of "future memory," an area that encompasses prospective memory (remembering to do something in the future), planning, strategizing, and preparing for interruptions, has traditionally concerned the roles of attention and working memory, and has largely overlooked the area of individual differences (Brandimonte, Einstein, & McDaniel, 1996; Gillie & Broadbent, 1989; Mumford, Schultz, & VanDoorn, 2001; Schunn & Reder, 2001; see Cherry & LeCompte, 1999, for an exception in prospective memory). For example, Gillie and Broadbent (1989) examined characteristics of interruptions that cause them to be disruptive to individuals. However, this research did not attempt to determine what characteristics of the interrupted individual caused them to be more or less prone to disruptions.

As an example of a future memory task, consider an air traffic controller who must monitor the current aircraft in his or her airspace; watch for incoming aircraft, make adjustments to aircraft depending on other aircraft or weather conditions, and update information regarding the airspace. The controller's performance may depend on his or her working memory span, ability to adjust to changes, and ability to detect changes in a complex environment. These skills, in turn, depend on the individual.

Recently, paradigms have been developed that can provide insight into the role of working memory and attention, as well as cognitive individual differences, when an individual is performing a future memory task. For instance, a number of complex, dynamic tasks have been developed that approximate real-world tasks and enable researchers to monitor participants' responses, strategies, and errors. For example, *Space Fortress*, a video game developed as a research tool, enables researchers to collect detailed records of participants' performance, including response times, strategies, and overall performance indicators such as total score, (Donchin, Fabiani, & Sanders, 1989; Mané & Donchin, 1989). These data can then be used to examine differences in performance due to workload differences, training programs, and a variety of other variables.

Many of these recently-developed tasks have strong ties to real-world tasks, such as the Kanfer-Ackerman Air Traffic Control Task (KA-ATC; Kanfer & Ackerman, 1989) and the Federal Aviation Administration's Air Traffic Scenarios Test (ATST; Broach & Brecht-Clark, 1994), in which participants control dynamic air traffic similar to an air traffic controller, and the Multi-attribute Task Battery (MAT-B; Comstock & Arnegard, 1992), in which participants visually and aurally monitor and adjust a number of gauges. Similarly, Synwork1 (Elsmore, 1994) was developed to approximate a comparable type of monitoring environment, but includes components that necessitate increased use of working memory. Along with the development of these complex, dynamic tasks, a number of measures of individual differences have been developed which enable psychologists to explore the underlying causes of differential behavior or skills. The present research is designed to identify individual difference factors that influence strategic performance on a future memory task that might be subject to change when different demands are placed upon the individual.

Strategies are methods or plans that individuals use to enable them to solve a problem or complete a task. A number of prior studies have shown that individuals differ in the strategies they use (Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Chi, Feltovich, & Glaser, 1981; Ericsson & Polson, 1988; Larkin, McDermott, Simon, & Simon, 1980; Reder, Wible, & Martin, 1986; Shapira & Kushner, 1985; Siegler, 1983). For instance, Chi et al. (1981) showed that individuals differed in the strategy they used to solve problems. In their study, novice and expert participants were asked to solve a series of physics problems. They found that novices were more likely to group problems based on similarities (e.g., slope, angle, etc.) whereas experts grouped problems based on the physics principles that applied to the solutions (e.g., conservation of energy). Thus, the experts' strategy of isolating the underlying principle helped them to find more efficient solutions to the problems than did novices.

A number of theories exist to explain strategy selection and strategy adaptation (alteration of a strategy to make it more effective). Schunn and Reder (2001) reviewed three of these theories: the parameter approach, the strategies approach, and the strategy adaptivity approach. The parameter approach suggests that performance differs in terms of some parameter of an individual's cognitive architecture, such as processing speed or working memory capacity. Thus, someone with a faster processing speed would outperform someone with a slower processing speed. The strategies approach suggests that performance varies based on the strategies that individuals choose to use. For example, one individual may choose to use an inefficient strategy, and would be outperformed by someone who chose to use a more efficient strategy. Finally, the strategy adaptivity approach suggests that performance is dependent on the adaptivity of the strategies that have been selected from a number of available strategies. Thus, all individuals use more than one strategy, and performance is dependent on how and when they apply the various strategies.

Generally, models of strategies do not take into account individual differences underlying strategy selection (John & Lallement, 1997; Lee, Anderson, & Matessa, 1995). However, Schunn and Reder's parameter approach accounts for an individual differences perspective. For instance, in this framework, operators' working memory capacities determine the type of strategy they are able to use on a given task. Therefore, this framework defines boundaries under which operators are able to utilize one strategy or another. Thus, the present research uses the parameter approach as a fundamental framework to guide assumptions and conclusions.

While there has been a great deal of research conducted on the general topic of strategy use and adaptivity, little research has been directed at which cognitive factors predict an individual's strategy use or strategy selection. Two models of strategies will be presented here. First, Damos and colleagues' examination of individual differences in multitasking will be presented (Damos & Smist, 1981; Damos & Wickens, 1980), followed by a study in which cognitive individual differences were used to assign participants to groups (Bleckley, Durso, Crutchfield, & Khanna, under review). The studies are similar in that the researchers used individual differences to separate participants. However, they differ in the "origin" of the individual difference on which that separation was based. Damos and colleagues separated participants based on behavioral processes, whereas cognitive individual differences (mental processes) were used to distinguish among groups in the second study.

Damos and Wickens (1980) were the first to examine individuals' strategies for multitasking as a factor in predicting performance. They divided participants based on choice of strategy in multiple-task conditions. Participants were instructed to perform two tasks simultaneously: either a short-term memory task with a classification task, or two tracking tasks. In Damos and Wickens' short-term memory task, random digits between 1 and 4 were presented sequentially. Participants were instructed to hold the most recently presented digit in memory and respond with the previous digit using a four-choice keyboard. For example, a participant might be presented with the following list of digits, "4,2,1,3" and the correct response to the "3" would be a "1." The second task was a classification task in which two randomly selected digits were presented simultaneously to the participant. The digits varied on two dimensions: size and name. The participant was to determine the number of dimensions on which the digits were alike, and select the corresponding key on a three-choice keyboard. For example, if the digits were alike in size and name, the participant would select a '2.' In the other condition, the two tracking tasks consisted of two one-dimensional compensatory tracking tasks. The goal was to keep a moving circle centered in a horizontal track by manipulating a control stick. Each hand controlled one task. The participants learned the two tasks (classification and tracking) simultaneously, and participated over two consecutive days.

Participants were classified according to the response strategy that they employed on the discrete task combination. Damos and Wickens identified three strategies that participants used: a simultaneous response strategy, an alternating strategy, and a massed strategy. In the simultaneous strategy, participants responded to both stimuli within a small interval (< 100 ms). Participants using an alternating strategy alternated responding to tasks (i.e., first respond to task A, then task B). Participants using a massed strategy made more than one response to one task before switching to another.

Subsequent studies examined whether these strategy groups differed in performance on a variety of combinations of multiple-task scenarios. Using the strategy classification of Damos and Wickens (1980), Damos and Smist (1982) demonstrated differences in performance across a variety of task combinations. Participants were instructed to perform a variety of combinations of tracking, memory, classification, and listening tasks. The tracking, memory, and classification tasks were the same as those used in Damos and Wickens (1980); the listening task comprised two conditions: selective listening and dichotic listening. In the selective listening condition, participants concentrated on information presented to one ear, while ignoring information presented to the unattended ear. In the dichotic listening task, participants attended equally to information presented to both ears. Individuals participated for four consecutive days. The first day consisted of training on the different tasks. The second, third, and fourth days consisted of blocks of dual-task trials separated by single-task trials. For instance, participants first performed blocks of single task tracking trials, and subsequently performed two blocks of five dual-task trials. The same pattern was used for selective listening and dichotic listening trials, and finally, the same pattern was again used for memory and classification trials. Participants who used the massed response strategy performed worse on the memory-classification task than those that used the alternating or simultaneous strategies. Damos and Smist hypothesized that this was because they processed information differently than those that used the other strategies. In their second experiment, Damos and Smist showed that the massed strategy participants were unable to switch to another strategy, even when given practice using the other strategy. Damos and Smist concluded that response strategies reflect individual differences in information processing in multi-task environments. Damos and colleagues showed that individual differences are responsible for the type of strategies that people use, and their ability to adapt those strategies as necessary. However, they did not explore these differences, nor attempt to explain why individuals choose one strategy over another.

An example of strategic differences based on cognitive individual differences is the concept of "controlled attention" (Bleckley, Durso, Crutchfield, & Khanna, under review; Engle, Kane, & Tuholski, 1999; Kane, Bleckley, Conway, & Engle, 2001; LaPointe & Engle, 1990). The ability to flexibly allocate one's attention is an individual difference that determines performance on a task (Engle et al., 1999; Kane, Bleckley, Conway, & Engle, 2001; LaPointe & Engle, 1990). For instance, in a study on visual attention allocation, Bleckley, Durso, Crutchfield, and Khanna (under review) measured individuals' operation spans (OSPAN), a measure of one's ability to compute mathematical operations and hold information in working memory, using the Operation Span (OSPAN) task (LaPointe & Engle, 1990; this task will be presented in the following section in greater detail). Individuals with high and low operation spans were instructed to allocate attention to two locations simultaneously: a central location and one of three rings surrounding the central location. Participants were then cued as to which ring to focus on; 23% of the time, participants were miscued. Analyses of the miscued trials indicated that individuals with a high operation span had more flexible attention – they were better able to "focus" their attention on particular areas of a task, and to ignore certain areas, whereas those with lower operation spans were less able to control their attention. For instance, if instructed to focus on the center and outermost ring, a high-span individual would focus on the center and outermost ring, without noticing information on the rings in between. In contrast, a low-span individual would focus on the center and outermost ring, but would also attend to information on the rings in between. Extrapolating from Bleckley et al.'s study, it is likely that a high-span individual could exhibit a "hybrid" of focused and distributed attention, where he or she is focused on certain areas of a task, but can still distribute attention to other areas. For instance, air traffic controllers might focus attention on part of their task (e.g., separating two airplanes), but still distribute some attention to another part (e.g., accepting incoming traffic from another sector).

Damos and colleagues identified strategy selection as a variable that influenced performance in a multitasking scenario. Bleckley et al. (under review) showed that cognitive individual difference factors have an effect on the way individuals perform tasks. For example, one's working memory (WM) capacity dictates how much information can be held in WM to be used on concurrent tasks, or to remember to perform a task when a signal is given. Thus, a large WM capacity may enable an individual to use a focused attention strategy, in which information from specific areas is attended to. Likewise, one's perception of a multitasking environment as a single integrated task, rather than a series of smaller tasks, may make the operator more likely to use a distributed-attention strategy, where all components of the task are equally attended to.

As mentioned previously, there are a number of future memory tasks that could be used as an environment in which to investigate cognitive individual differences. In the present studies, Synwork1 was selected as the simulated work environment. Briefly, Synwork1 is a simulated work environment comprising four quadrants. In each quadrant, a different task is presented: a memory task (modified Sternberg task), a math task (addition), an auditory monitoring task, and a visual monitoring task. Points are earned for performing well in each task, and are deducted for errors. Operators are instructed to perform as well as possible to maximize their scores. A task analysis of Synwork1 showing necessary actions, feedback, and potential errors, was conducted, and appears in Figure 1.

Recently, Rickard (1997, p. 288) called for, "...programmatic research that explores the mechanisms of strategy choice and the factors influencing their operation (e.g., Anderson, 1993; LeMaire & Siegler, 1995; Reder & Ritter, 1992)." A few studies have answered that call; investigations of strategy adaptivity (Schunn, Lovett, & Reder, 2001; Schunn & Reder, 2001) and the relationship between cognitive processes and strategies (McNamara & Scott, 2001) have been conducted recently. However, none of these studies has determined whether mental processes such as cognitive individual differences affect strategy choice in multitasking. The present study seeks to determine which of four cognitive individual difference factors are potential predictors of strategy use in a multitasking scenario. Each of the measures is outlined below.

Individual Difference Measures

Field Dependence/Independence

The cognitive style of "field dependence" is measured with the Embedded Figures Test (Witkin, Oltman, Raskin, & Karp, 1971). In this test, individuals are given a limited amount of time to find a series of simple figures that are embedded within more complex figures. A field dependent (FD) individual's perception is strongly dominated by the overall organization of the surrounding field, and parts of the field are experienced as "fused." In contrast, one that perceives in a more field independent (FI) manner experiences part of the field as discrete from the organized ground. Several studies have shown that this cognitive individual difference factor extends beyond visual perception to a variety of areas of cognitive function (Bennink & Spoelstra, 1979; Davis & Frank, 1979; Durso, Reardon, & Jolly, 1985; Jolly & Reardon, 1985; Reardon & Rosen, 1984). In fact, Witkin (1979) suggested that one's tendency toward field dependence or independence is evident in all of one's psychological and neurophysiological activities. Jolly and Reardon (1985) conducted a study that showed differences in how FD and FI participants monitored the environment when interrupted. In their study, participants believed that they were helping the experimenter prepare for an unrelated experiment by organizing scoring sheets and recording responses (CVC trigrams) and figures from a televised display. The participants performed this highly repetitious task over 60 trials, during which they experienced severe and mild interruption of the cover task. In the mild case, the participant discovered a blank response sheet, and in the severe condition, the participant discovered a blank response sheet and the televised display briefly flashed. Following the trials, the participants rated their confidence that a particular trigram or figure had been presented. Jolly and Reardon found that once interrupted, FI individuals monitored the material more closely than did FD individuals. Thus, they suggested that FI individuals have a more narrow, efficient focus on task material, in contrast to FD individuals, whose focus is broader and less well defined.

In a multitasking environment, it may be important to perceive the task as a unified whole, rather than as a task comprising several separate subtasks (Gopher & Kimchi, 1989). Gopher and Kimchi suggested that two properties of human perception "are responsible for this effect: (1) the human perceptual system has a limited ability to process a single dimension with multiple objects at the same time, while it is capable of processing in parallel several dimensions of a single object (e.g., Kahneman & Treisman, 1984; Lappin, 1967), and (2) global or holistic features can be processed faster than local features (e.g., Navon, 1977, 1981; Pomerantz, 1981) (1989, p. 437)." Therefore, FD individuals should perform better than FI individuals on tasks that have many interrelated components. Moreover, because FD participants will perceive the entire task as one, they will be more likely to work on all components of the task at once, thereby distributing attention to all components equally. In the Synwork1 task, this might translate into responding to stimuli from all four tasks as necessary. In contrast, FI individuals, who are more likely to perceive the various components of a task as separate, will be more likely to make more than one response to one component before moving to another. This might lead to a distributed attention strategy, where some information is focused on, while other information is ignored. In Synwork1, individuals using this strategy would make more than one response in each task before moving on to the next task.

Working Memory Capacity

Working memory comprises three systems: an executive controller and two slave systems (Baddeley & Hitch, 1974). The executive controller is a mechanism that directs attentional resources to the slave systems when necessary. The executive controller performs other functions as well, such as sequencing information, monitoring information, and monitoring the current status of the system. Most recently, Baddeley (1993) has proposed that his working memory model is better represented as a "working attention" model. Using this model, the control of attention is one of the primary functions of the central executive. Although the working attention model has many supporters (among them the originator of working memory), a clear adoption has yet to be made by all memory researchers. However, most researchers would agree that the attentional system is closely linked with the working memory system.

Engle, Cantor, and Carullo (1992) proposed a general capacity model of working memory (WM) that accounts for individual differences in WM capacity. In this model, information in WM is hypothesized to be information from long-term memory (LTM) that has been activated beyond a threshold level. Unlike other models that suggest that processing efficiency is the cause of individual differences in WM span, Engle et al.'s model suggests that individuals differ in the total amount of activation available to retrieve information from LTM. That is, individuals do not differ in terms of WM capacity but in terms of activation.

The Operation Span test (OSPAN; Engle, Kane, & Tuholski, 1999; La Pointe & Engle, 1990) is a measure of working memory capacity and of attention-shifting ability or "flexible attention." In a testing session, participants read a mathematical formula, solve it, and subsequently read a word. A number of such trials are performed, after which, they are asked to recall the entire list of words presented in the trial (the list of words randomly varies from 2-6). To perform this task successfully, the participant must not only solve the operations and read the words, but also must keep track of the continually increasing number of words on the list.

Engle, Cantor, and Carullo (1992) suggested that OSPAN measures amount of activation because it requires attention-switching between the maintenance of information (words) and problem solving (math problems). If this is so, then individuals with large operation spans should perform better on tests of multitasking ability because they have greater capacity with which to remember to switch among a task's component parts.

In a study similar to the present study, Crutchfield, Bleckley, and Durso (2000) used OSPAN as a predictor in an air-traffic control task. In this task, participants controlled dynamic air traffic using a computerized simulation program. OSPAN was negatively related to the number of control errors made in this task, but was not related to the other dependent variables in the simulation, such as missed readback errors and penalties. Apparently, other cognitive factors besides OSPAN were responsible for performance on the task. One such factor may be strategy use.

Individuals with a high OSPAN would likely respond to all components of a task in a small amount of time. An individual with a high OSPAN would have the resources available to schedule, monitor, and act on a strategy such as this. Bleckley, Durso, Crutchfield, and Khanna (under review) found that high OSPAN individuals most often use a focused-attention strategy. Following Bleckley et al., high OSPAN individuals would likely continue to use a focused attention strategy. For instance, in the Synwork1 task, high OSPAN individuals would be likely to alternate among all four tasks very quickly, making responses in each task. In contrast, an individual with a low OSPAN would likely use a strategy in which he or she moves from one component of the task to another, making one response in each component. This strategy would be beneficial to someone with a lower OSPAN because he or she could depend on an established pattern to determine which components had been responded to. Because the working memory system's central executive is responsible for monitoring and coordinating of this nature, this strategy would alleviate the need for an individual to use WM resources to monitor. This would free resources for use elsewhere, effectively reducing the cognitive load experienced by the individual. For instance, in the Synwork1 task, individuals using this strategy might make one response in the Sternberg quadrant, followed by one response in the Math quadrant, followed by one response in each of the Auditory and Visual Monitoring quadrants. Alternatively, low OSPAN individuals could utilize strategies that tax their abilities, negatively affecting performance. This might be due to the individual being unaware that using a different strategy would reduce their cognitive load. Thus, instead of using a set pattern as a framework by which to make responses to the task, one might attempt to give equal attention to all components of the task, as did Bleckley et al.'s low OSPAN participants. In the Synwork1 task, this would look much like a high OSPAN individual's strategy. However, performance (i.e., score, accuracy, etc.) would be lower. Low OSPAN individuals might be more likely to use a distributed attention strategy, or a hybrid strategy that engages components of both focused and distributed attention strategies.

Executive Control

The Wisconsin Card Sorting Test (WCST; Nelson, 1976) was designed as an assessment tool for abstract reasoning and ability to switch strategies as necessitated by the environment (Heaton, Chelune, Talley, Kay, & Curtiss, 1993). Today, it is widely used as a measure of executive control capability. Using a computer program, participants categorize a stack of electronic "cards" based on a rule that changes periodically among three different rules, color (red, yellow, green, or blue), number of items (one, two, three, or four), and shape (circle, square, star, or triangle). Once the rule changes, the participant must change his or her mapping rule. For example, if the rule were "color," participants would sort the cards according to the colors of the shapes on the cards. However, when the rule changed to "number," participants would need to immediately begin sorting based on the number of items on the card. When used as a measure of executive control capability, three dependent measures are of particular interest: learning to learn, failure to maintain set, and percent perseverative errors.

The WCST requires strategic planning, organized searching, and use of feedback to update cognitive set and direct behavior toward a goal, which are all executive control functions (Heaton, Chelune, Talley, Kay, & Curtiss, 1993). The frontal lobes of the brain are generally believed to house executive control. In patients with frontal lobe lesions, an inverse relationship has been found between error measures on the WCST and executive functioning (e.g., Dehaene & Changeux, 1991). Thus, error measures on the WCST have been shown to be a good indicator of one's executive control capabilities.

The number of perseverative errors is indicative of executive control failure. A perseverative error occurs when an individual continually responds incorrectly to a stimulus, even though they are informed of the incorrect response. For instance, a participant may attempt to sort the cards based on color, and given feedback to inform them that this is incorrect. However, the participant continues to sort based on the incorrect rule. Perseverative errors demonstrate a failure to monitor for rule changes.

In addition to error measures, researchers use the "learning to learn" variable as a measure of efficient learning on the WCST. Learning to learn refers to a participant's improvement in efficiency over consecutive categories (i.e., color, shape, and number). A positive learning to learn score indicates that the participant has become more proficient in sorting all categories of the WCST. Thus, learning to learn is used as an overall indication of performance on the WCST.

The error measure most related to future memory performance is "failure to maintain set" (Marsh & Hicks, 1998). For instance, this occurs when an individual is supposed to sort cards according to color, and successfully executes the rule five times, but subsequently fails to execute that same rule. This error is indicative of a monitoring failure because participants have failed to respond to a change in the environment. Recently, monitoring failures have been investigated within the field of prospective memory.

Prospective memory refers to remembering to perform a task in the future. There are two primary types of prospective memory, event-based and time-based. Event-based means that the cue to perform the task is based on some event, external or internal (e.g., remember to take medication when eating lunch); time-based means that the cue to perform the task is a specific time (e.g., remember to go to a meeting at 3:00). Marsh and Hicks (1998) examined event-based tasks. They had participants complete a cognitively demanding star counting task while also randomly generating numbers. Prior to beginning each trial, participants were presented with three words and instructed to strike a key if they heard a word that referred to a type of fruit (i.e., the prospective response). This task was essentially a vigilance task, where participants monitored information and made a response when appropriate. Consequently, errors on this task were considered monitoring failures. Marsh and Hicks found poorer performance in event-based prospective memory tasks when participants had to complete concurrent tasks known to demand executive resources. They concluded that prospective remembering was dependent on the same resources that support successful monitoring, especially the contribution of the central executive in working memory.

Because event-based prospective memory requires the same executive resources as monitoring, a multitasking scenario that necessitates constant monitoring should require the same resources. Because attentional capacities are related to central executive functioning, poor performance in a multitasking scenario would be predicted for those with low executive control capacity. Thus, individuals with a low executive control capacity would be expected to use a distributed or hybrid attention strategy because their cognitive resources would not support their focusing on information. In Synwork1, this might translate into a strategy where a "pattern" is employed to add structure to the task, which benefits the participant by freeing up mental resources to be used elsewhere. Thus, an individual with low executive control resources might make one response in each task before moving to another task, or might create another pattern that would help them to keep track of their responses. In contrast, an individual with higher executive control capacity would be expected to excel in monitoring, coordinating, and remembering information pertaining to the task and could schedule efficiently. Thus, higher executive control individuals would be likely to use a focused attention strategy. In Synwork1, individuals using this strategy would probably move among the four tasks, making responses in each quadrant whenever necessary.

Comfort with Situational Ambiguity

The Need for Closure Scale (NFCS; Webster & Kruglanski, 1994) is a measure of an individual's preference for situational ambiguity. The scale measures how comfortable someone is in uncertain or ambiguous situations. The scale consists of five subscales measuring preference for order, preference for predictability, decisiveness, discomfort in ambiguity, and closed-mindedness.

Webster and Kruglanski suggested that when importance is placed on predictability, need for closure increases. Similarly, need for closure increases when time pressure creates a need to complete a task by a certain deadline. Due to the unpredictable and dynamic nature of the multitasking environment, individuals who have a high need for closure may find working in this environment undesirable. As a result, their performance may suffer. In contrast, those with a lower need for cognitive closure may not find the multitasking environment as undesirable, and suffer no decrement in performance. In terms of strategy selection, one who is high in need for closure might select a strategy that forces artificial structure onto the task, unlike an individual lower in need for closure, who would not have the desire to create structure where there was none.

Need for closure has been shown to affect a number of social-cognitive phenomena, among them medical decision making (Cofrin, 2000), consumer behavior (Houghton & Grewal, 2000), and negotiating behavior (De Grada, Kruglanski, Mannetti, & Pierro, 1999). For example, Cofrin (2000) conducted a study in which medical students diagnosed high- and low-urgency medical cases (emergencies and nonemergencies), under high and low uncertainty conditions. Participants in the high uncertainty condition were provided only a limited amount of information about the patient, whereas in the low uncertainty condition, participants were given further information. Cofrin found that participants that scored high in need for closure reported greater confidence in their diagnoses at the end of the case workup than those that scored low in need for closure. Thus, the individual's need for closure affected the level of confidence in a decision.

No research has examined need for closure in relation to a cognitive-based motor task, like a multitask environment. An individual with a high need for closure might use a strategy that enabled him or her to add structure to a multiple task environment. This could be achieved by using a strategy where one response is made to each component of the task before moving to the next component. By setting up a kind of "pattern," more structure is added to the task. Thus, in Synwork1, high NFC individuals might make one response in each task before moving to another. Individuals scoring high on Need for Closure might use a focused attention strategy, which enables the operator to monitor the areas within the task that are most easily controlled and ignore the components that are difficult to control. In contrast, an individual with a lower need for closure might choose a strategy that was less rigid, enabling the individual to monitor all components of a task, whether they could be controlled or not. In Synwork1, low NFC individuals might respond to stimuli only as they occur, rather than utilizing a more proactive strategy.

Taken together, these four individual difference variables are strong candidates for cognitive factors that might influence individual performance on a multitasking scenario. Moreover, because these factors affect outward behavior in a number of cases, they are likely influences on strategy selection in a multitasking scenario such as Synwork1.

Because there is no research identifying cognitive factors that influence strategy selection in multitasking, Experiment 1 was performed to determine which cognitive individual difference factors predicted strategy choice in a future memory (multitasking) scenario.

Experiment 1

An exploratory study was conducted to determine the most relevant individual difference factors and dependent variables in the Synwork1 multitasking environment (Elsmore, 1994).

Method

Participants. Thirty-one undergraduate students at the University of Oklahoma participated as one alternative for fulfilling an introductory psychology course research involvement component. Of the 31, 11 were male, and 20 were female. Participants' ages ranged from 18 to 23, with a mean age of 19.

Materials. The Need for Closure Scale (NFCS), Operation Span test (OSPAN), Group Embedded Figures Test (GEFT), and the Wisconsin Card Sorting Task (WCST) were administered to participants. The WCST and the OSPAN test were administered via computer; the GEFT is a paper and pencil test that was administered in groups of about five. Synwork1, a computerized synthetic work environment, was used as the multitasking environment. A short questionnaire regarding strategy use was administered after each Synwork1 session. A pilot study was conducted in which 5 students performed the Synwork1 task for 60 minutes (2 sessions of 30 minutes each) and generated all possible alternative strategies. Once all possibilities were generated, a team of researchers analyzed the results to determine the number of unique strategies. A questionnaire that contained open-ended questions resulting from pilot testing was then prepared for use after each scenario, and is included in the Appendix. Open-ended choices were provided for participants to select the strategy that best described the way they performed the scenario. Participants were instructed to select the strategy that best described their performance and fill in the blanks. For instance, one might have selected "I ignored the ________ task altogether and focused equally on the other 3 tasks," and filled in the blank with "math."

Synwork1 presents a screen with four quadrants; in each quadrant, a different task is presented (see Figure 1). In the upper left quadrant, a Sternberg memory task is presented: participants are shown a list of six letters and are instructed to memorize the letters. At various intervals, single letters are presented on the screen, and participants use the mouse to select "yes" or "no" responses, based on whether or not that letter had been presented. If an individual needs to see the letters again, they can select a button that presents the letters again for approximately three seconds. Ten points are subtracted when participants incorrectly identify a letter in the Sternberg task and when they recall the list of letters.

In the upper right quadrant, participants are presented two, three-digit numbers positioned one above the other (and both above a summation line) representing a standard mathematical addition problem. Using the mouse, participants point to locations below the summation line and with each click of the mouse, increment or decrement digits to represent the accurate sum of the two digits above the summation line. Once they have finalized their sum, participants use the mouse to click on an "end" button, which clears the sum and displays a new set of digits to add. Ten points are subtracted when participants submit an incorrect sum in the math quadrant.

In the lower right quadrant, a high and low auditory tone task is presented. Tones sound randomly at one-second intervals throughout the entire session. Participants must respond whenever a high tone is presented, and select the "high tone" button; no response is required when a low tone is presented. Ten points are subtracted when participants fail to respond to a high tone or respond incorrectly to a low tone.

In the lower left quadrant, participants monitor a vigilance task consisting of a sliding bar that moves from one end of a line to the other. Participants are instructed to reset the bar to the center by selecting a "reset" button with the mouse whenever the bar gets close to an end. Participants lose 10 points each time the bar reaches the end of the line and lose 10 more points for each subsequent second that it is not reset.

Participants are not told how many points are added or deducted from their score, but this information can be determined by monitoring the overall score, which is presented in the center of the screen. Experimenters instructed the participants that the tasks in the four quadrants were equally important and that they should work on all four tasks to maximize their scores.

Throughout the 15-minute session, Synwork1 was presented at a "moderate" workload level. Workload was determined to be moderate based on a pilot study that indicated that participants could respond to the four tasks, but the pace was challenging.

Twenty-six dependent measures are recorded during every Synwork1 session: six each for the Sternberg and Math tasks, five for the visual monitoring task, and seven for the auditory monitoring task. Two additional measures were also included: composite score and mean response rate. A list of the dependent measures, along with their descriptions, is shown in Table 1.

Procedure. Students who participated in the introductory psychology course mass testing session previously were administered the Need for Closure scale. Students were randomly selected to participate in the study, regardless of their score on the Need for Closure scale.

The experiment was conducted over three one-hour sessions. On Day One, participants completed the OSPAN test and the Wisconsin Card Sorting Test. After these measures were administered, participants trained on the Synwork1 multitasking environment. Training lasted for 15 minutes, during which each task was presented in isolation for three minutes. During this time, experimenters observed the participants to ensure that they understood the goal of each task and how points could be gained or lost. After the initial training, participants completed one, 15-minute practice session. On Day Two, experimenters administered the Group Embedded Figures Test (GEFT), after which participants completed one, 30-minute session of Synwork1. On Day Three, participants again completed one, 30-minute session of Synwork1, followed by a questionnaire regarding strategy use on the OSPAN and Synwork1 tasks (see Appendix).

Results and Discussion

Individual Difference Factors

Scores on the four cognitive individual difference tests were collected. Table 2 shows ranges and mean scores for the four cognitive individual difference variables, including three subscales of the WCST and the five subscales of the Need for Closure Scale. For several of the scales used, there are no standardized values to determine in which group an individual's score lies (i.e., Field Dependent vs. Field Independent). For these scales, group membership is relative, based on the other participants' scores.

There are no standardized values to determine whether an individual is Field dependent or Field independent. Rather, a relative judgment is made. Individuals scoring in the lowest third (4-8) were labeled as Field Dependent, whereas those in the highest third (14-18) were labeled Field Independent. The mean score on the GEFT was 11.77, which was comparable to the original normative sample's median for men and women in (Witkin et al., 1971), as well as mean scores from recent studies using GEFT (see Härtel, 1993).

The highest possible score on the OSPAN test is a 60, and the lowest possible score is a zero. Generally, participants whose scores are nine or below are considered low OSPAN, and those that score 18 and above are considered high OSPAN (Turner & Engle, 1989). OSPAN scores ranged from five to 45, with a mean of 13.The range of scores and mean score is comparable to OSPAN scores from another study (Bleckley & Engle, 2002).

Three measures were presented from the Wisconsin Card Sorting Task: Percent correct, percent perseverative errors, and learning to learn. Overall, ranges and mean values were comparable to those from participants in the original normative study (Heaton, Chelune, Talley, Kay, & Curtiss, 1993).

Six measures from the Need for Closure Scale were included: the total score and scores on each of the five subscales. There are no standardized high or low NFCS scores, instead extreme scores are defined in relation to the others in the sample, generally through using a median split, which was used here. The NFCS scores from this sample were low in comparison to previous studies (Klein & Webster, 2000; Webster & Kruglansksi, 1994). However, ranges in scores were similar to ranges from prior studies.

In all analyses that will be presented here, scores were standardized to aid in comparisons between factors. A correlation analysis was performed on the standardized scores from the cognitive individual difference factors to determine what relationships among the variables existed. The correlation matrix (Table 3) shows significant correlations among several variables. For instance, scores on the GEFT were correlated with scores on the WCST learning to learn measure, indicating that as one's GEFT score increased (as an individual became more field independent) they were able to learn more effectively (adapt strategies/mapping codes) in the WCST. A number of the NFCS subscales were positively correlated with the NFCS total score. Although we normally would have used either the total score or the subscales, the subscales have important differences among them (and the tolerance for ambiguity subscale has show important effects in multitasking), so we thought it important to keep the subscales separate and part of the correlation analysis to follow.

Synwork1

The 15-minute Synwork1 session on Day 1 was treated as a training session, and those data are not included in the analyses presented here. Data from 26 dependent variables were collected for each participant during trials on Days 2 and 3. The 26 variables included a variety of measures of score and response rate from each task, as well as variables unique to the particular tasks. For instance, in the Math task, the number of increments and decrements were recorded, and in the Visual Monitoring task, the number of resets and lapses were recorded.

Dependent sample *t*-tests (alpha controlled) were performed on these data, comparing days 2 and 3 (note that there were no changes from Day 2 to Day 3). Table 4 shows means for each variable and *t*-values for each test. Few of the variables significantly differed from Day 2 to Day 3. Those that differed were mainly measures of score, and can be considered practice effects. For example, comprehensive score, score on math task, number of problems on the math task, and the number of decrements on the math task differed from Day 2 to Day 3.

Strategies

Did individuals elect to use different strategies on the Synwork1 task? At the conclusion of the second Synwork1 session, participants completed a brief questionnaire regarding the strategy(ies) they used. Strategy types were defined by participants' self-reports of the strategy employed (see Appendix). Participants circled the strategy that best described their performance. Four strategy types were represented based on the circled strategies: those that focused on a single task (Focus 1), those that focused on two tasks (Focus 2), those that ignored one task and focused on the remaining three (Focus 3), and those that focused equally on all four quadrants (Focus 4). Table 5 provides descriptions of the strategy types that were reported and the proportion of participants who reported using each of the strategies.

Logistic Regression.

To assess whether cognitive individual differences predicted strategy type, a backwards logistic regression was performed with strategy (Focus 1-4) as outcome with eleven cognitive predictors: Field dependence/independence, OSPAN, percent correct on the WCST, percent perseverative errors on the WCST, learning to learn on the WCST, and NFCS total score, NFCS preference for order subscale, NFCS preference for predictability subscale, NFCS decisiveness subscale, NFCS dislike for ambiguity subscale, and NFCS close-mindedness subscale. Due to the exploratory nature of this study, all five subscales of the NFCS were included. Furthermore, Neuberg, Judice, and West (1997) suggested that without considering the subscales, overall score might not give an accurate understanding of one's need for cognitive closure. After deletion of one participants' data that had missing values, data from 30 participants were included in the analyses.

Logistic regressions are used to predict discrete outcomes such as group membership from discrete or continuous variables. The goal is to emphasize the probability of a particular outcome for a case. For instance, it evaluates the probability that a given individual used Strategy X, given that individual's pattern of scores on cognitive individual difference tests. In a logistic regression, a nonlinear model is used to evaluate relationships among variables, rather than the general linear model (Tabachnick & Fidell, 1996). As a result, instead of fitting a straight line to all the known values as in the general linear model, the logistic model can fit a curve to data. In a backward logistic regression, factors are removed from the full model (the model including all of the predictor variables), until the best-fitting model is reached. Once removed from the model, factors are not added back into the model.

Table 6 shows regression coefficients for each of the predictors included in the model. Of the eleven predictors, nine were included in the model. Significant predictors included one's field dependence/independence, total score on the WCST, percent correct on the WCST, and all of the Need for Closure variables: total score, preference for order subscale, preference for predictability subscale, decisiveness subscale, dislike for ambiguity subscale, and closed-mindedness subscale. Thus, three factors: field dependence/independence, executive control, and Need for Closure predicted participants' reported strategy selection when the Synwork1 task was presented at a moderate level.

Table 7 shows mean standardized scores for each of the predictors by type of strategy used. In order to determine whether there were differences among strategies based on cognitive individual differences, an ANOVA was performed. There were no significant differences among strategies in terms of cognitive individual differences. However, a marginal difference existed among strategies in terms of OSPAN, $F(3, 27) = 2.32$, $p = .10$. *Fisher's LSD* post hoc tests showed that Focus 1 (focus on one task) differed from Focus 2 (focus on two tasks), and that Focus 2 differed from Focus 4 (equal distribution among the four tasks). Those individuals that used Focus 2 had a higher (standardized) mean OSPAN score ($M = .75$) than those that used Focus 1 ($M = -.22$) or Focus 4 ($M = -.36$). Apparently, those that had more processing resources available were more likely to focus their attention between two primary tasks, rather than focusing on one task or distributing their attention equally among all four tasks. Although differences among strategies were found only within one cognitive individual difference factor, attention should focus on the results of the logistic regression, which showed that NFCS factors were important in terms of predicting group membership. Fundamentally, the two tests that were used (i.e., logistic regression and ANOVA) were different. Whereas logistic regressions emphasize the probability of a particular outcome for a case, ANOVAs evaluate differences among means relative to their distribution in a sample

(Tabachnick & Fidell, 1996). Thus, although there were no significant differences among strategies in terms of cognitive individual differences, the cognitive individual differences were able to differentially predict strategy.

Based on the results of Experiment 1, we determined that the OSPAN, Wisconsin Card Sorting Test and Need for Closure Scales are important predictors of performance on the Synwork1 task under moderate workload. Based on the measures identified in the Experiment 1, and extending the work of Damos and Wickens (1980) and Damos and Smist (1982), Experiment 2 sought to determine which cognitive individual difference factors serve as predictors of strategy use under different workload conditions in a future memory task.

Experiment 2

Experiment 1 showed that strategies differed among individuals, and that these strategies could be predicted using cognitive individual difference factors. Because some strategies are more effective and require less effort to reach the same level of performance as others, we hypothesized that workload would affect strategy selection. Experiment 2 focuses on two questions: Do cognitive individual differences predict strategy selection under high and low workload levels in a future memory task and Is there an objective measure of strategy that provides support for participants' subjective self-reports?

In order to understand differences that might occur due to workload it is important to first understand the cognitive processes that underlie workload. In this section, a brief review of the major theories of capacity will be reviewed in examining the concept of workload.

The concept of attentional capacity serves as a framework for numerous theories of mental workload. A number of these "limited processing capacity" theories have been proposed through the years (Broadbent, 1958; Kahneman, 1973; Wickens, 1984). For instance, Kahneman proposed a capacity model of mental processes in which resources for all processes are allocated out of a central pool of resources. Under this model, if an individual attends to too many stimuli or attempts to perform too many simultaneous tasks, performance breaks down. In contrast, Wickens' (1984) Multiple Resource Theory posits that individuals have separate pools of resources, which allocate resources independently from other pools. For instance, under this model, an individual would have separate pools for auditory and visual processing. Thus, if they were to carry out tasks that use resources from separate pools, such as bouncing a ball (i.e., visual processing) while engaging in conversation (i.e., auditory processing) no interference should occur. However, if the individual carries out tasks that require a great deal of resources from one pool (e.g., carrying on a very difficult conversation), performance breaks down. Although the single and multiple-resource models disagree on the structure of the resource pools, researchers from both camps concur that the amount of resources available to process information at any given time is limited and processing breaks down when the resources become overloaded.

Workload is generally defined as the demands of the task coupled with the effects of those demands on the operator (Gopher & Donchin, 1986; Kantowitz, 1987). The concept of workload relies on the fundamental assumption that processing resources are limited. Accordingly, workload is relative: it is dependent upon the demands of the task in addition to the amount of resources the operator is able or willing to allocate to the task. Research has shown that workload can negatively impact operator performance (Vidulich & Wickens, 1986; Xie & Salvendy, 2000; Yeh & Wickens 1988). For example, an air traffic controller's job requires monitoring and guidance of approximately ten to twenty aircraft as they pass through his or her airspace. Controllers perform this task extremely well and are able to carry on conversations while controlling traffic. However, when air traffic increases the controller may become unable to keep up outside conversation. Because workload increased, more processing resources are necessary to perform the task at the same level of performance. Thus, an increase in workload can have deleterious effects on a task that is extremely well known by the operator.

Strategy use can reduce the deleterious effects of workload by enabling the operator to intake and process an overall greater amount of information about the task environment. The use of strategies, or techniques that are used to reduce the amount of material to be processed, allows operators to regulate their performance by performing tasks using fewer cognitive resources than they would otherwise require (McNamara & Scott, 2001). For instance, Sperandio (1971) showed that air traffic controllers strategically adapted to an unexpected workload increase by spending less time processing each aircraft in the sector. This strategy enabled the controllers to manage their workload, maintaining performance at a high level. Other strategies that are often used by air traffic controllers to reduce information processing include ceasing less important tasks, increasing aircraft spacing, and preventing aircraft from entering the sector (Wickens, Mavor, & McGee, 1997). Thus, a variety of strategies can be used to lessen workload and maintain high performance. In professions such as air traffic control, where errors can result in human safety issues, maintaining high levels of performance is of considerable importance. In fact, Moray (1988) suggested that allocating optimal mental workload to operators would result in fewer errors, improved safety, increased productivity, and operator satisfaction.

The amount of expertise or training an operator has with a task may have a considerable effect on his or her performance. As operators become more familiar with a task, the system in which it exists, and its physical characteristics, they generally begin to perform better on the task. With expertise, the operator is able to use his or her understanding of the system and the physical characteristics of the environment to his or her advantage. A great deal of top-down knowledge is available to help guide the distribution of attention (Durso & Gronlund, 1999), freeing up resources that would otherwise be used in attending to a variety of stimuli in an attempt to recognize and select out the relevant information. With expertise, some components of the task become automatized. That is, they would no longer require *any* cognitive resources to be performed, or only a negligible amount (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977).

The advantage of expertise may also impact the number of strategies that are used by an operator. Experts are said to use fewer strategies than non-experts, and their strategies are more often correct (Charness, 1976). For example, a novice helicopter pilot may believe that a good strategy for maintaining training course accuracy is to ignore incoming communications. Although this may work in the short-term, it would be a poor long-term strategy, as incoming communications might act to update pilots on the status of various parts of the training course. Likewise, novice operators often try a variety of strategies, and retain unhelpful strategies for a longer period of time than is practical (Charness, 1976).

It is clear that strategies can improve performance by streamlining information processing and reducing cognitive workload. However, research in the domain of strategies suffers from its lack of objectivity. The objective assessment of strategies is a common problem in strategy research, and is one for which there is no easy solution. Determining what strategy an individual has used can be a difficult process, as participants may be unable to articulate their strategy for the researcher. The responsibility for determining which strategy was used then falls with the experimenter, and is generally accomplished through observing or interviewing participants, both of which may be subject to experimenter biases. Ideally, participants should report their strategies to researchers. However, Nisbett and Wilson (1977) suggested that individuals often cannot access their mental processes, and instead, their reports are said to be the "most plausible accounts" of the cognitive process that took place, rather than a true account of the process. However, it is possible for some tasks that strategies are largely conscious, rather than automatic processes, and individuals should be able to access and report their strategies reliably. For example, in playing complicated video games, individuals are conscious of the strategies that they employ, and as a result, should be able to describe them reliably.

The present study will examine three objective measures of strategy selection to determine whether they affirm the subjective self-reports of participants' strategy selection on the Synwork1 task. Among the objective measures are 1) the proportion of time spent in each of the four tasks, 2) the proportion of responses made in each task, and 3) the transitions made among the four tasks.

Method

Participants. Thirty-three undergraduate students at the University of Oklahoma participated as one alternative for fulfilling an introductory psychology course research involvement component. Of the 33, 17 were males and 16 were females. Participants' ages ranged from 18 to 20, with a mean age of 18.9.

Materials. Participants were tested with the GEFT, OSPAN, WCST, and NFCS tests. Although OSPAN was not a significant predictor in Experiment 1, it was included in this experiment because OSPAN has been shown to predict performance under conditions of differing workloads (see Bleckley et al., under review). Therefore, although OSPAN did not predict strategy selection under moderate workload levels, we hypothesized that it would under high and low workload levels.

Two versions of Synwork1 were programmed. One version of Synwork1 was programmed to be presented at a high workload level (Difficult Condition), and another version was programmed to be presented at a low workload level (Easy Condition). These workload levels were operationally defined based on results from a pilot study in which a variety of workload levels were examined. The workload levels were selected based on participants' reports of difficulty level and whether they were able to complete the task. In the easy condition, the math task was constant; new math problems appeared as soon as the participant selected the "done" button. The auditory monitoring task had an inter-tone interval of three seconds, with a 15% probability of a positive tone occurring. In the visual monitoring task, the scale (line) was created of 201 pixels. The "interstep interval" refers to the number of milliseconds required to move one pixel. In the easy condition, the interstep interval was 100. Finally, in the Sternberg task, the amount of time between probes was 15 seconds. In the difficult condition, the math task was constant; new math problems appeared as soon as the participant selected the "done" button. The auditory monitoring task had an inter-tone interval of two seconds, with a 25% probability of a positive tone occurring. In the visual monitoring task, the interstep interval was 75. Finally, in the Sternberg task, the amount of time between probes was five seconds. After each Synwork1 session, participants completed questionnaires regarding strategy use (see Appendix).

Procedure. Individuals participated for three days. On day one, participants completed the individual differences tests and trained on the Synwork1 task at a moderate level of workload (the same workload level used in Experiment 1). On the second and third days, participants completed half-hour sessions of Synwork1. On one day, the participant was presented with an "Easy" or "Difficult" condition, and on the other day, the other condition. Order of presentation was counterbalanced. After each Synwork1 session, participants completed a questionnaire regarding the strategy/ies used in that session (see Appendix).

Experiment 2 was designed to assess two problems: a) whether it is possible to objectively assess whether individuals use different strategies, and b) which cognitive factors, if any, predict those strategies.

Results and Discussion

Individual Difference Factors

Table 8 shows ranges and mean scores for the four cognitive individual difference variables, including three subscales of the WCST and the five subscales of the NFCS. For several of the scales used, there are no standardized values to determine in which group an individual's score lies. For these scales, group membership is relative, and is based on the other participants' scores. The mean score on the GEFT was 12.64, which was comparable to the mean from Experiment 1. The mean score on OSPAN was 12.38. The maximum score was considerably lower in Experiment 2 than in Experiment 1, although the mean score remained comparable. The participants in the present study had a similar range and mean score as those in Bleckley et al.'s (under review) study. Three measures were presented from the Wisconsin Card Sorting Task: Percent correct, Percent perseverative errors, and learning to learn. Overall, ranges and mean values were comparable to scores from participants in Experiment 1. Six measures were included for the Need for Closure Scale: the total score and scores on each of the five subscales. The Need for Closure Scale total scores ranged from 108 to 144, with a mean of 109.83. Overall, scores were lower in Experiment 2 than in Experiment 1, as were ranges within scores. In Experiment 1, the mean range of the subscales was 17.6, in comparison with Experiment 2, where the mean range of the subscales was 11.4.

In all analyses that follow, scores were standardized to aid in comparisons between factors. A correlation analysis was performed on the standardized scores from the cognitive individual factors. The correlation matrix, shown in Table 9, shows a number of significant correlations among variables. For instance, scores on the GEFT were negatively correlated with percent perseverative errors on the WCST as well as the

NFCS total score, preference for order, and closed-mindedness. Thus, as one's ability to perceive simple tasks embedded within complex tasks improves, their ability to change mapping rules as necessary in the WCST decreases, as do their scores on the NFCS (including preference for order and closed-mindedness subscales). Overall, there were fewer significant correlations in Experiment 1. As Table 3 shows, in Experiment 1, WCST Learning to Learn was positively correlated with GEFT and WCST percent correct. Not surprisingly, WCST percent correct was also negatively correlated with WCST percent perseverative errors. As in Experiment 2, a number of significant correlations existed among NFCS factors in Experiment 1.

Similarly, the NFCS Tolerance for Ambiguity subscale was positively correlated with the NFCS total score as well as the other four subscales. Thus, as one's tolerance for ambiguity increased, so did total NFCS score, preference for order, preference for predictability, decisiveness, and closed-mindedness. Although we normally would have used either the total score or the subscales, these subscales have important differences among them (and the tolerance for ambiguity subscale has shown important effects in terms of multitasking), so we thought it important to keep the subscales separated in the correlation analysis and those to follow.

Synwork1

The 15-minute Synwork1 session on Day 1 was treated as a training session, and those data are not included in the analyses presented here. Days 2 and 3 included an Easy session and a Difficult session. Data from 26 dependent variables were collected for each participant during trials on Days 2 and 3. Of the 26, only 11 variables used the same base rate on days 2 and 3. That is, comparing the response rate on the auditory monitoring task between days 2 and 3 was inappropriate because there were more opportunities to respond in the Difficult (higher workload) session than in the Easy (lower workload) session. The variables that used the same base rate on days 2 and 3 included percent errors, omissions, and overall percent correct on the Sternberg Task; all variables on the math task (recall that the math task was individually paced in the sense that each time the "done" button was selected, a new math problem appeared); average distance from center in the visual monitoring task; and percent signals detected in the auditory monitoring task.

Dependent sample *t*-tests (controlling for alpha) were performed on these data. Table 10 shows means for all of the variables and *t*-values for the eleven tests. A number of the variables differed significantly from Day 2 to Day 3. In the math task, participants responded faster and completed more problems in the Easy session than in the Difficult session (as a function of completing more problems, participants also incremented and decremented the sum more in the Easy condition). Similarly, more auditory signals were detected in the Easy condition than in the difficult condition. Given that workload was greater in the Difficult condition, it is not surprising that fewer signals were detected.

Strategies

Did individuals elect to use different strategies on the Synwork1 task? At the conclusion of the second Synwork1 session, participants completed a brief questionnaire regarding the strategy(ies) they used. As in Experiment 1, participants self-reported the strategy they used. Based on these self-reports, experimenters divided participants into six strategy types: Participants who used Focus 1 focused on one task, and responded to the other three only when necessary. Participants who used Focus 2 focused on two tasks, and responded to the other two tasks when necessary. Participants who used Focus 3 ignored one task altogether and focused on the remaining three tasks. Participants who used Focus 4 divided their focus equally on two tasks, and equally on the remaining two tasks. For instance, participants might have given 30% of their attention to the math and auditory monitoring tasks, and 20% of their attention to the Sternberg and visual monitoring tasks. Participants who used Focus 5 divided their attention equally among the four tasks. Participants who used Focus 6 used a unique strategy that could not be classified as any of the above strategies (thus, the individuals in this group may have little in common). Table 11 provides descriptions of the six strategy types that were reported as well as the proportion of individuals who used the strategies under both Easy and Difficult conditions. Because self-reports of performance are often considered to be inaccurate reflections of actual performance (Nisbett & Wilson, 1977), we undertook a number of analyses to determine whether a more objective measure of strategy selection could be determined that could confirm the self-report data.

A problem occurs in the analyses to follow that might obscure the unique contribution of individual strategies. Generally, individual scores are pooled together and comparisons among groups are conducted. However, in this case, participants that used the same strategy might have focused on entirely different tasks. For example, two participants may have used Focus 1, but one focused on the Math task and the other focused on the Sternberg task. Though the two strategies differ specifically, they would be very similar conceptually. Although these participants would have been accurate in reporting their strategy, any analyses based on similarities between the two strategies would not be meaningful. Therefore, although the analyses to follow were based on groups of participants, individual examples of strategies will be considered.

Time on Task

One way to operationalize strategy is to measure the proportion of time spent in each of the four tasks for each of the six strategies[1]. For example, if participants focus on a particular task, they should spend more time in that task. Proportions were calculated by dividing participants' total time spent (in seconds) in each task by the total time spent in the four tasks. Table 12 shows the proportion of response times spent in each task in the Easy and Difficult conditions by strategy[2]. An Analysis of Variance was performed on Condition (Easy, Difficult) x Strategy (Focus 1-6; based on self-reports) x Task (Math, Sternberg, Auditory Monitoring, Visual Monitoring). Because there was only one participant each who reported using Focus 3 and Focus 4 in the Easy condition, these cells were not included in the analysis. There was no 3-way interaction of condition x strategy x task, $F(9, 216) = 1.45, p > .05$. However, there was a significant interaction of condition x task, $F(3, 216) = 39.38, p < .05$. Participants in the Difficult condition spent 15% more time on the Sternberg task than they did in the Easy condition, and spent 22% less time on Math problems than in the Easy condition. There was also a significant interaction of strategy x task, $F(15, 216) = 2.85, p < .05$. Differences in the amount of

[1] An alternative method of analyzing these data would be to collapse across specific tasks, and instead create categories based on participants' primary focus, secondary focus, tertiary focus, etc. This type of analysis might eliminate effects that were simple artifacts of one of the Synwork1 tasks (such as spending more time in the math task because there is more to do in that task, such as incrementing and decrementing sums).

[2] Because the math task in Synwork1 differs from the other three tasks in that multiple responses are required to answer one problem (multiple increments or decrements), analyses that are presented here and in Experiment 2 may show differences that are simply artifacts of the math task (i.e. greater proportion of time spent in the math quadrant). A better version of Synwork1 for this type of analysis would be a 2-AFC (Alternative Forced Choice), where participants would be presented with two numbers to sum, and two possible answers would be presented. The participants' task would be to select the correct answer from the two alternatives (the correct answer would always be presented). This adaptation to the current Synwork1 program would improve the comparability among tasks.

time devoted to the Math task were dependent on condition. For example, participants who used Focus 1 in the Easy condition spent 43% of their time in the Math task, compared with those who used the same strategy in the Difficult condition, who spent only 18% of their time in the Math task.

Overall, participants spent less time in the Visual Monitoring task, and even less in the Sternberg and Auditory Monitoring tasks. Given the nature of these tasks, this result is not surprising. The Sternberg and Auditory Monitoring tasks require only simple responses based on presented information (e.g., if the tone was high, select the 'high tone' button; if there was an 'S' in the Sternberg list, select "yes," if not, select "no"). In contrast, the Math and Visual Monitoring tasks required more complex responses. For instance, in the Math task, participants continually summed and submitted values. As a result, participants spent considerably more time on the Math task than the other three tasks. This effect may have been an artifact of the Synwork1 task, where the Math task is continually presented (and responses are therefore continually possible), in contrast to the other three tasks, in which responses are possible intermittently.

Because averaging across individual strategies can dilute the unique contribution of a particular strategy, individual strategies that best represented the type of strategy used were selected as examples. Table 13 shows individual participants' proportions of time in tasks in Easy and Difficult conditions. Clearly, the focus of the participant that self-reported using Focus 1 in the Easy scenario was on the Math task, which accounted for 61% of all of the time during the scenario. Although time was spent in each of the three other tasks, the participant focused mainly on the one task. The participant who reported using Focus 2 (focus on two tasks) in the Easy scenario focused on the Math and

Auditory Monitoring tasks, which represented 25% and 38%, respectively, of all time spent in the scenario. Although the difference in the proportion of the two main tasks is large, in comparison to the other tasks, it is clear that the participant's focus was on these two tasks. There was only one participant who used Focus 3 (focus on three tasks, ignoring one task) in the Easy scenario. The Math, Auditory Monitoring, and Sternberg tasks were the center of activity for this participant, accounting for 26%, 51%, and 11% of the total amount of time in the scenario, respectively. The Visual Monitoring task accounted for 12% of the total time. Likewise, there was only one participant who used Focus 4 (spent equal time among the tasks) in the Easy scenario, and the pattern in this example is not well defined. Although the individual spent time in each of the four quadrants, an equal distribution of time among the tasks is not well illustrated. In fact, the distribution of time shows that more time was spent in the Math quadrant (48%) than the Sternberg (13%), Auditory Monitoring (29%), or Visual Monitoring (10%) quadrants. For the participant who reported using Focus 5 (equal time in 2 tasks, equal time in the other 2 tasks), the Math and Auditory Monitoring tasks are roughly equivalent (28% and 35%, respectively), as are the Visual Monitoring Reset and Sternberg tasks (23% and 14% respectively). Several participants reported utilizing a strategy that could not be categorized into any of the other five presented previously. In the example provided in Table 13, the participant focused on three of the four tasks and completely ignored the fourth task (Sternberg task). This differs from Focus 3 (focus on three tasks, ignoring one task) in that this participant completely ignored the fourth task, unlike any of the participants in Focus 3, who spent time in all four tasks but focused on three of the four tasks.

The participant who used Focus 1 (focus on one task) in the Difficult scenario clearly focused on the Visual Monitoring task, which is apparent from the proportion of time spent in that task, which accounted for 57% of total time during the scenario. Time was spent in each of the other three tasks; however, this participant's focus was mainly on the Visual Monitoring task. The participant that used Focus 2 (focus on two tasks) in the Difficult scenario spent the most time in the Math and Visual Monitoring tasks (25% and 40%, respectively. The participant who used Focus 3 (focus on three tasks, ignoring one task) in the Difficult scenario made roughly 0% of their total responses in the Math task. The Auditory Monitoring, Visual Monitoring, and Sternberg tasks were this participant's focus, and represent 55%, 9%, and 35% respectively, of total responses in the scenario. The participant who reported using Focus 4 (spent equal time among the tasks) did not respond fairly equally in all four tasks: the Math task accounted for 13% of all activities during the scenario, the Auditory monitoring, Sternberg, and Visual Monitoring tasks accounted for 44%, 31%, and 11% of all activities during the scenario, respectively. The participant who reported using Focus 5 (equal time in 2 tasks, equal time in the other 2 tasks) did not respond to two tasks fairly equally and to the other two tasks fairly equally. In this example, the Sternberg task (25%) and the Visual Monitoring task (21%) are fairly equivalent, but the Math and Auditory Monitoring tasks are not at all equivalent (4% and 49%, respectively). This strategy also differed from Focus 2 (focus on two tasks) in that the proportions of time in the two secondary tasks in Focus 2 were not equivalent. The participant who utilized a strategy that could not be categorized into any of the five presented previously focused on three of the four tasks and completely ignored the fourth task (Math task). Because this participant spent no time whatsoever in the Math task, they were classified as different than those participants who reported using Focus 3.

In some cases, it is not obvious from the percentage of time spent in each task that the task was "focused on" or "not focused on." It may be the case that when the participant self-reported the strategy that he or she used, what was meant by "focusing on" a particular task may not have been captured by time spent on the task, but instead reflects something else (e.g., effort or difficulty level). An alternative to this analysis would be to analyze the number of "units" completed in each task (i.e., in the math task, the number of times the participant selected the "done" button), rather than the amount of time spent on the task, or the proportion of responses in the task.

Overall, differences in the amount of time spent on each task existed as a function of strategy, and also by condition. Taken together, these results show that the overall amount of time that participants spent in each of the four tasks provided some support for participants' self-reported strategies.

An alternative way to measure strategy use is the number of responses made in each task. To assess this, we examined the proportion of responses in each task, in Easy and Difficult conditions, based on the six self-reported strategies.

Responses in Quadrant

An alternative to operationalizing strategy based on the amount of time spent on each task is to focus on the number of responses made on each task for each of the six self-reported strategies. Proportions were calculated by dividing participants' number of responses made in each task by the total number of responses in the four tasks. A three-way ANOVA comparing proportions of responses in each of the four tasks based on the six self-reported strategy types in the Easy and Difficult scenarios was computed. Because there was only one participant each who reported using Focus 3 and Focus 4 in the Easy condition, these cells were not included in the analysis. There was no 3-way interaction of condition x strategy x task, $F(9, 216) = 1.68, p > .05$. Similar to time on task, however, there were *significant* interactions of condition x task, $F(3, 216) = 35.05, p < .05$, and of strategy x task, $F(15, 216) = 3.84, p < .05$. Table 14 shows the proportion of responses in each task in the Easy and Difficult conditions. Not surprisingly, the patterns of proportions were similar to those from Time on Task, with most of the responses being made in the Math and Visual Monitoring tasks.

In the Difficult condition, participants' responses on the Sternberg task, Auditory Monitoring task, and Visual Monitoring task all increased over the Easy condition (increases ranging from 13%-18%), with a 31% decrease in responses in the Math condition. Given the increase in workload, it is not surprising that participants altered the way in which they responded to the tasks. Similarly, increases in responses in the Sternberg and Auditory Monitoring tasks in the Difficult condition account for the significant strategy x task interaction.

Because averaging across individual strategies can dilute the unique contribution of a particular strategy, individual strategies that best represented the type of strategy used were selected as examples. Table 15 shows individual participants' proportions of responses in tasks in Easy and Difficult conditions. Clearly, the focus of the participant that self-reported using Focus 1 in the Easy scenario was on the Math task, which accounted for 87% of all of the activities during the scenario. Although responses were made in each of the three other tasks, the participant focused mainly on the one task. The participant who reported using Focus 2 (focus on two tasks) in the Easy scenario focused on the Math and Auditory Monitoring tasks, which represented 66% and 24%, respectively, of all activities during the scenario. Although the difference in the proportion of the two main tasks is large, in comparison to the other tasks, it is clear that the participant's focus was on these two tasks. There was only one participant who used Focus 3 (focus on three tasks, ignoring one task) in the Easy scenario. The Math, Auditory Monitoring, and Sternberg tasks were the center of activity for this participant, accounting for 69%, 15%, and 9% of the total responses made in the scenario, respectively. The Visual Monitoring task accounted for 7% of the total responses. Likewise, there was only one participant who used Focus 4 (spent equal time among the tasks) in the Easy scenario, and the pattern in this example is not well defined. Although the individual made responses in each of the four quadrants, an equal distribution of responses among the tasks is not well illustrated. In fact, the distribution of responses shows that more responses were made in the Math quadrant (81%) than the Sternberg (6%), Auditory Monitoring (9%), or Visual Monitoring (4%) quadrants. For the participant who reported using Focus 5 (equal time in 2 tasks, equal time in the other 2 tasks), the Math and Auditory Monitoring tasks are roughly equivalent (64% and 27%, respectively), as are the Visual Monitoring Reset and Sternberg tasks (3% and 4% respectively). Several participants reported utilizing a strategy that could not be categorized into any of the other five presented previously. In the example provided in Table 15, the participant focused on three of the four tasks and completely ignored the fourth task (Sternberg task). This differs from Focus 3 (focus on three tasks, ignoring one task) in that this participant completely ignored the fourth task, unlike any of the participants in Focus 3, who made responses in all four tasks but focused on three of the four tasks. Overall, the proportions of responses in each quadrant in the Easy condition showed some support for individual differences based on strategy use.

The participant who used Focus 1 (focus on one task) in the Difficult scenario clearly focused on the Auditory monitoring task, which is apparent from the proportion of responses made in that task, which accounted for 72% of all activities during the scenario. Responses were made in each of the other three tasks; however, this participant's focus was mainly on the Auditory monitoring task. The participant that used Focus 2 (focus on two tasks) in the Difficult scenario focused on the Math and Auditory Monitoring tasks (61% and 20%, respectively. The participant who used Focus 3 (focus on three tasks, ignoring one task) in the Difficult scenario made only 2% of their total responses in the Math task. The Auditory Monitoring, Visual Monitoring, and Sternberg tasks were this participant's focus, and represent 30%, 26%, and 42% respectively, of total responses in the scenario. The participant who reported using Focus 4 (spent equal time among the tasks) responded fairly equally in all four tasks. The Math task accounted for 44% of all activities during the scenario, the Auditory monitoring, Sternberg, and Visual monitoring tasks accounted for 19%, 24%, and 13% of all activities during the scenario, respectively. The participant who reported using Focus 5 (equal time in 2 tasks, equal time in the other 2 tasks) responded to two tasks fairly equally and to the other two tasks fairly equally. In this example, the Math and Visual Monitoring tasks are roughly equivalent (16% and 18%, respectively in comparison with the Auditory monitoring and Sternberg tasks (39% and 28%, respectively). This strategy also differed from Focus 2 (focus on two tasks) in that the proportions of the two secondary tasks in Focus 2 were not equivalent. The participant who utilized a strategy that could not be categorized into any of the five presented previously focused on three of the four tasks and completely ignored the fourth task (Math task). Because this participant made no responses whatsoever in the Math task, they were classified as different than those participants who reported using Focus 3.

Overall, individuals' self-reports of strategies corresponded with data from the proportion of responses in each task in eleven of twelve cases. Thus, the proportion of responses in each task showed support for participants' self-reported strategies.

As a third method of operationalizing strategies, we examined the pattern of transitions from one quadrant to another. For instance, two participants may use different strategies: one participant may respond once in each task prior to moving to another task, and the other participant may simply respond as necessary to each task (i.e., reset the visual monitoring task when it reaches the end and respond to auditory monitoring cues when necessary, while performing addition in between). In the first example, the participant put structure into the task whereas in the second example the participant merely reacted to environmental cues. These two participants may have earned the same amount of points, or spent the same amount of time in the various quadrants, yet how they did the task differed. To assess whether the pattern of transitions made by participants would be predictive of strategy self-reports, we used Pathfinder Network Graphical Analyses.

Pathfinder Network Graphical Analyses

A Pathfinder network is a graphical analysis tool used to show associations between variables, which are represented as nodes and weights of those associations, which are represented as links (Schvaneveldt, Durso, & Dearholt, 1989). Past research has used Pathfinder networks to illustrate data in natural concepts, experts and novices, and basic-level categories (Schvaneveldt, Durso, & Dearholt, 1989). For instance, Schvaneveldt et al. used word association norms to create Pathfinder networks for six categories: three for basic-level categories (e.g., bird, tree) and three for non-basic level categories (e.g., clothes, fruit). Basic level categories are those that are used in conversations with others; these categories are considered to be neither specific nor general, and are generally represented with a single word (e.g., "bird") (Reisberg, 1997). Schvaneveldt et al. showed that Pathfinder networks for basic-level categories were considerably different from categories that were not basic-level. Basic-level categories showed a central node with links to nodes attached to the center, whereas in other categories, the central node was not as distinct, and there were many links among nodes. Thus, a Pathfinder network allowed for one of the fundamental principles of the basic-level category (representation with a single word) to be captured in a graphical representation.

A Pathfinder network can be considered a type of "grammar" for what types of responses are allowed or not allowed in a scenario. In Pathfinder Networks, association between the nodes is represented by the size of the links. For instance, two nodes that are closely related will have thicker links connecting them, whereas nodes that are less related will be connected by thinner links; unrelated nodes will not be linked at all. Some nodes link back to themselves, creating "loops." The node size represents how frequently the variable was utilized. Thus, a large node is representative of a variable that is frequently utilized.

Based on individuals' self-report data, we conducted Pathfinder Graphical Network Analyses to attempt to provide an objective measure of each strategy. Individual Pathfinder networks were created for each of the thirty-three participants for the Easy and Difficult scenarios. To create networks, transitions among every component of the Synwork1 task that required a response were summarized in matrices. The matrices contained the number of transitions from task n to task $n + 1$, resulting in a 13 x 13 matrix for each participant. For example, if a participant reset the bar in the visual monitoring task, and then responded to a letter in the Sternberg task, the cell corresponding to that transition would be incremented. To allow comparisons among participants, each 13 x 13 matrix consisted of the proportions, rather than raw frequencies, of times that a particular transition had been made. Parameter values that resulted in the sparsest Pathfinder graphs (i.e., the minimum number of links) were created: q was set to 12 (13 categories minus 1), and r (the value of the Minkowski distance metric) was set to ∞. If a transition did not reach a particular threshold, it was not included in the network. As a result, some nodes were not connected by links. Likewise, nodes that failed to reach the minimum threshold level were very rarely used, and were represented in networks as small circles (shaded yellow).

Often, Pathfinder networks are pooled together and analyses of similarities among groups are conducted. However, in this case, participants that used the same strategy might have focused on entirely different areas. For example, two participants may have used Focus 1, but one focused on the Math task and the other focused on the Sternberg task. The two networks would look quite different and an average of the two would look nothing like either original. These participants would have been accurate in reporting their strategy, but any analyses based on similarities between the two networks would not be meaningful. Therefore, analyses of similarities among networks will not be presented here and individual networks must be considered. Individual Pathfinder networks were created for all participants, and samples from each of the six strategy types were selected for use as an example. Figures 3-8 show the Pathfinder networks representative of each of the six strategy types that were reported being used by participants. In all but one case, we found clear examples of Pathfinder networks that supported individuals' self-reports.

In the following sections, all of the networks in the Easy condition will be described, followed by the networks in the Difficult condition. Especially noteworthy in these descriptions are examples of nodes, links, and cycles that show a particular node being emphasized or a series of links common to multiple networks.

Easy Scenario

The upper panel of Figure 3 shows a Pathfinder network from a participant who used Focus 1 (focus on one task) in the Easy scenario. Clearly, the focus of this individual was on the Math task (all elements of the focused task are shaded blue). Although responses were made in each of the other three tasks, the participant focused mainly on the one task. The pattern of transitions among responses included a loop within the task that was the participants' main focus within the math task, incrementing the sum. In this example, the participant frequently made successive increments to the sum, which is illustrated by the loop in the pattern of transitions among the responses, which indicated that the individual might have worked on completing a math problem before moving to a different task. When the participant occasionally completed another task (e.g., Sternberg task), he or she began the cycle at Auditory Monitoring and returned to

Auditory Monitoring. The link from Auditory Monitoring to incrementing in the Math task was heavy, which illustrated that the transition was made often. Interestingly, the Sternberg task was only linked to the Auditory monitoring task, and the Visual monitoring task was only linked with the Math task. This suggests that a) the Sternberg and Visual Monitoring tasks were not used often and b) the proportion of times that this participant traveled from any particular node to the Sternberg or Visual Monitoring nodes was lower than the threshold used to determine whether a link should be represented. Likewise, the proportion of times the participant selected an incorrect response, or retrieved a list in the Sternberg task, as well as the proportion of times the participant experienced a lapse in the visual monitoring task, were below threshold and those nodes were not represented.

The lower panel of Figure 3 shows a Pathfinder network from a participant who used Focus 2 (focus on two tasks) in the Easy scenario. In this scenario, the participant focused on the Math and Auditory Monitoring tasks (these tasks are shaded blue in the figure), which represented 66% and 23%, respectively, of all activities during the scenario. Although the difference in node size is large, in comparison to the other nodes in this network, it is clear that the participant's focus was on these two tasks. This strategy differed from Focus 1 in the number of links in the network. Focus 2 has nearly twice as many links as Focus 1, suggesting that individuals made more transitions among tasks. As in Focus 1, the primary tasks (Math and Auditory Monitoring) show loops indicating more than one successive response on the tasks. Thus, as in Focus 1, this participant often transitioned from incrementing a sum in the Math task to incrementing the sum again. Likewise, this participant also made successive correct responses in the

Auditory Monitoring task. This participant also moved frequently between the Auditory Monitoring task and the Math task, which is illustrated in the network by the two-way arrows (links) connecting the two nodes, indicating that this participant transitioned between the two nodes. This link is also heavier than all other links in the network, suggesting that this pattern occurred frequently. This network also shows a number of cycles that connected the two primary tasks (e.g., Auditory Monitoring correct →Math decrement→ Math increment→ Math correct→ Auditory Monitoring correct), as well as multiple transitions between tasks. As an example of the latter, this participant transitioned between the Auditory Monitoring task and the Sternberg task, which is illustrated in the network by the two-way link connecting the two nodes.

The upper panel of Figure 4 shows the Pathfinder network from the participant who used Focus 3 (focus on three tasks, ignoring one task) in the Easy scenario. Only one individual selected this strategy in the Easy scenario. The Math, Auditory Monitoring, and Sternberg tasks were the center of activity for this participant (the three tasks appear shaded in the figure). There are large loops on two components within one of the tasks (Math incrementing and Math decrementing), showing successive responses to the same component. Interestingly, the network shows that the Sternberg task is most often responded to before or after the Auditory Monitoring task. This network shows much of the same structure as Focus 2. This participant's pattern of responses shows links between Math and Sternberg nodes and VM and Sternberg nodes, which suggests that responses may not have been made using a "pattern," where responses to tasks are alternated. Instead, this pattern is more indicative of responses that occurred in no particular sequence.

The lower panel of Figure 4 shows the Pathfinder network from the participant who used Focus 4 (spent equal time among the tasks) in the Easy scenario. Only one individual reported using this strategy in the Easy scenario, and the pattern in this example is not well defined. Although the individual made responses in each of the four quadrants, the Pathfinder network does not illustrate an equal distribution of responses among the tasks. In fact, the distribution of responses shows that more responses were made in the Math quadrant (69%) than the Sternberg (9%), Auditory Monitoring (15%), or Visual Monitoring (7%) quadrants. A possible explanation for the lack of similarity between this participant's self-reported strategy and the objective strategy measure is that this participant *attended* equally to the four tasks, yet did not make responses equally among tasks. That is, the participant may have spent a great deal of time monitoring the four tasks, but only responded to the tasks when necessary. Thus, although the participant may have reported the correct strategy (focused equally on all four tasks), the objective data showed more responses in one quadrant than the others. This example of Focus 4 illustrates the same structure as in Focus 2 and Focus 3. However, Focus 4 shows fewer links between Sternberg responses and Auditory Monitoring responses and more links to and from Math incrementing. This example seems to be indicative of an individual who reported using a pattern or attempted to place a structure on the task.

The upper panel of Figure 5 shows a Pathfinder network from a participant who reported using Focus 5 (equal time in 2 tasks, equal time in the other 2 tasks). In this example, the Math and Auditory Monitoring tasks are roughly equivalent (63% and 29%, respectively; represented by blue shading), as are the Visual Monitoring Reset and Sternberg tasks (3% and 5% respectively; represented by light blue shading). Clearly, more responses were made in the Math and Auditory Monitoring tasks. However, this strategy differs from Focus 2 (focus on two tasks) because of the distribution of responses. In Focus 2, more responses were made in the VM task than in the Sternberg task whereas in Focus 5, the proportion of responses made in the VM and Sternberg tasks were roughly equivalent. In Focus 5, we again see the large loops on the two primary tasks illustrating successive responses in a particular node.

The lower panel of Figure 5 shows a pathfinder network from a participant who utilized a strategy that could not be categorized into any of the other five presented previously. In this scenario, the participant focused on three of the four tasks and completely ignored the fourth task (Sternberg task). This differs from Focus 3 (focus on three tasks, ignoring one task) in that this participant completely ignored the fourth task, unlike any of the participants in Focus 3, who made responses in all four tasks but <u>focused</u> on three of the four tasks. Large loops and distinct links exist among the three remaining tasks, indicating that the individual made a number of transitions among those tasks, and followed the same pattern each time, from Auditory Monitoring to incrementing in the Math task, and after submitting the math sum, made a response in the Auditory Monitoring task. Although the pattern of transitions used in Focus 6 was unlike any of the other strategies used, there is a similar structure to the network. In particular, strong links between the Auditory Monitoring and Math incrementing and Math correct and incorrect and Auditory Monitoring correct are similar to patterns found in each of the other five networks.

There were a number of similarities across networks in the Easy condition. For example, the Math task was the focus in all of the networks. In all of the networks, participants focused on the Math task, resulting in large nodes. Also in every network, individuals made sequential responses to the Math task, resulting in loops within the Math task. Patterns of transitions among the tasks showed that the Sternberg task was almost always preceded by the Auditory monitoring task, but not the Math task. The Visual Monitoring task was generally preceded by the Auditory Monitoring task; in four of the six networks, the Auditory Monitoring task was the only node that preceded the Visual Monitoring node.

Difficult Scenario

The upper panel of Figure 6 shows a Pathfinder network from a participant who used Focus 1 (focus on one task) in the Difficult scenario. Clearly, the focus of this individual was on the Auditory monitoring task (shaded in blue), which is apparent from the size of the node, which accounted for 72% of all activities during the scenario. The pattern of transitions among responses included loops on the primary task, as well as on the Math task. Thus, the participant made successive responses on the Auditory Monitoring task. There is only one cycle in this network (e.g., Auditory Monitoring correct →Math decrement →Math increment →Math correct), and the Sternberg and Visual Monitoring tasks were only accessed after a correct response in the Auditory Monitoring task. It appeared that this participant created a structure in which responses to the other tasks were only made between responses to the Auditory Monitoring task.

The lower panel of Figure 6 shows a network from a participant who used Focus 2 (focus on two tasks) in the Difficult scenario. This participant's focus was on the Math and Auditory Monitoring tasks (54% and 20%, respectively; these tasks are shaded in blue in the figure). As in Focus 1, the Math task shows loops indicating that more than one successive response was made on the task. This network also shows a four-link cycle connecting the two primary tasks (Auditory Monitoring correct →Math decrement →Math increment →Math correct →Auditory Monitoring correct), and multiple simple transitions between quadrants. For instance, this participant transitioned between the Auditory Monitoring task and the Sternberg task, and the Auditory Monitoring task and the Visual Monitoring task. The structure of this network is similar to networks from the Easy scenarios, with heavy links between Auditory Monitoring and Math tasks and multiple links among Auditory Monitoring nodes and Sternberg nodes. This structure is also similar to that in Focus 1, with the exception of the difference in Auditory Monitoring and Math node sizes.

The upper panel of Figure 7 shows a network from a participant who used Focus 3 (focus on three tasks, ignoring one task) in the Difficult scenario. The three primary tasks appear shaded in blue in the figure. The Auditory Monitoring, Visual Monitoring, and Sternberg tasks were this participant's focus, and represent 29%, 27%, and 39% respectively, of total responses in the scenario. This network is interesting because there are no loops on the three primary tasks. This participant was less likely to make more than one response in the same quadrant than to make a single response in successive quadrants. Further support for this stems from the links among the three primary tasks. Several of these links are thick, indicating that this participant frequently made the same response among the three primary tasks. That is, this participant frequently transitioned from Stern correct Yes to Auditory Monitoring and from Auditory Monitoring to Visual Monitoring reset (and vice versa). The most distinctive difference about this network is that the Math node was the least frequently used, unlike any of the other networks presenseted. Because fewer responses were made in the math node, nodes in the three other tasks are considerably larger. Likewise, another unique characteristic of this network are the strong links among Sternberg and Auditory Monitoring nodes. However, much of the basic structure of the network is similar to those previously presented.

The lower panel of Figure 7 shows a network from a participant who reported using Focus 4 (spent equal time among the tasks). This example of Focus 4 illustrates a fairly even distribution of responses, as well as a structure that is similar to those in Focus 2 and Focus 3. In Focus 4, the Math task accounted for 44% of all activities during the scenario, the Auditory monitoring, Sternberg, and Visual monitoring tasks accounted for 18%, 21%, and 12% of all activities during the scenario, respectively. There were a number of cycles among the four nodes. For example, this network included a cycle that incorporated all four tasks: Auditory Monitoring correct →Math increment →Math correct →Visual Monitoring reset →Sternberg correct no. In addition, in the Math task, there is a large loop on the incrementing node, and a smaller loop on the decrementing node, illustrating that the participant made successive responses in the same task.

The upper panel of Figure 8 shows a network from a participant who reported using Focus 5 (equal time in 2 tasks, equal time in the other 2 tasks). In this example, the Math and Visual Monitoring tasks are roughly equivalent (15% and 17%, respectively; represented by blue shading) in comparison with the Auditory monitoring and Sternberg tasks (39% and 27%, respectively; represented by light blue shading). As in the Easy scenario, however, the distribution of responses caused this strategy to differ from Focus 2 (focus on two tasks). In this strategy, the proportion of responses in the Math and Visual Monitoring tasks (the two secondary tasks) is roughly equivalent as opposed to the secondary tasks in Focus 2. In this strategy, we again see cycles that include all four tasks, for instance Auditory Monitoring correct →Math decrement→ Math increment→ Math correct →Sternberg correct no→Auditory Monitoring correct→Visual Monitoring reset. Strong (thick) links exist between the AM task and correct responses on the Sternberg task, illustrating that these transitions occurred frequently. Loops on the Math incrementing and decrementing nodes also indicate that successive responses were often made within the Math task, a pattern that has been seen in many of the other networks. As in Focus 4, this participant made use of all four tasks fairly often. However, in Focus 4, the proportion of the responses made in each of the four tasks was different, whereas in this strategy, proportions were equivalent for two of the four tasks and proportions in the two other tasks were equivalent to one another. This strategy also differed from Focus 2 (focus on two tasks) in that the proportions of the two secondary tasks in Focus 2 were not equivalent.

The lower panel of Figure 8 shows an example from a participant who utilized a strategy that could not be categorized into any of the five presented previously. This participant focused on three of the four tasks and completely ignored the fourth task (Math task). As in the Focus 6 example from the Easy scenario, large loops and strong (i.e., thick) links exist among the three tasks that remain, indicating that the individual made a number of transitions among those tasks, including successive transitions in the Auditory Monitoring task. As in Focus 6 from the Easy scenario, this strategy differs from Focus 3 (focus on three tasks, ignoring one task) in that this participant completely ignored the fourth task, unlike any of the participants in Focus 3, who made responses in all four tasks but <u>focused</u> on three of the four tasks.

There were a number of similarities across networks in the Difficult condition. For example, the Auditory Monitoring task was the focus in many of the networks, indicated by large Auditory Monitoring nodes. As in the Easy condition, in every network, individuals made sequential responses to the same task, resulting in loops within the task. This generally occurred in the Math task, but also occurred in the Auditory Monitoring node in two of the six networks. Patterns of transitions among the tasks showed that the Sternberg task was almost always preceded and followed by the Auditory monitoring task. In two conditions, the Math task also preceded the Sternberg task. The Visual Monitoring task was generally preceded by the Auditory Monitoring task; in four of the six networks, the Auditory Monitoring task was the only node that preceded the Visual Monitoring node.

Overall, the results of the Pathfinder networks presented here provide support for the existence of the participants' self-reported strategies. These results, taken together with the results from the proportion of time spent in each task and the proportion of responses made in each task, indicate corroboration for individuals' self-reports of strategy use on the Synwork1 task. To determine whether cognitive differences underlie strategy selection differently depending on workload, logistic regressions were performed.

Logistic Regressions

In order to assess which cognitive factors predicted strategy selection, two backwards logistic regressions were performed using Strategy Type (based on self-report data) for each scenario (Easy, Difficult) as outcome. Eleven cognitive predictors were included: Field dependence/independence, OSPAN, percent correct on the WCST, percent perseverative errors on the WCST, learning to learn on the WCST, and NFCS total score, NFCS preference for order subscale, NFCS preference for predictability subscale, NFCS decisiveness subscale, NFCS dislike for ambiguity subscale, and NFCS close-mindedness subscale. After deletion of three participants' data that had missing values, 30 participants' data were included in the analyses.

Table 16 shows regression coefficients for each of the predictors included in the model for the Easy Condition. Of the eleven predictors, only the Need for Closure variables were included: total score, preference for order subscale, preference for predictability subscale, decisiveness subscale, dislike for ambiguity subscale, and closed-mindedness subscale. Though nonsignificant, the data show a trend for those individuals who scored higher on all Need for Closure subscales to use strategies that limit the amount of necessary cognitive processing. For instance, under high workload conditions, these individuals may elect to focus on one task, thereby limiting the amount of incoming information and effectively reducing workload. To someone with a high Need for Closure, this might be a more effective strategy than attempting to divide their attention equally among the four tasks.

One of the more important questions that these data can address is whether individuals using particular strategies differ in terms of cognitive individual difference factors. To assess whether strategies differed in terms of the cognitive individual difference factors, a series of ANOVAs were conducted, comparing cognitive individual difference factors as the dependent variables across strategies. Table 17 shows mean standardized scores for each of the cognitive individual difference factors in the Easy Condition. In the Easy condition, ANOVAs showed no significant differences by strategy, (all *Fs* < 1.75). Thus, although the logistic regression included the Need for Closure variables as predictors, those factors did not significantly differ from other cognitive individual difference factors. As in Experiment 1, these seemingly conflicting results can be explained by examining the statistical tests that were performed. Logistic regressions and ANOVAs evaluate different statistical "questions" (Tabachnick & Fidell, 1996). Although there were no significant differences among strategies in terms of cognitive individual differences, they were able to differentially predict strategy.

As in the Easy condition, a logistic regression was performed to predict strategy type based on cognitive individual difference factors in the Difficult condition. Table 18 shows regression coefficients for each of the predictors. In this condition, the OSPAN, percent correct on the WCST, percent perseverative errors on the WCST, and three NFCS subscales: total score, decisiveness, and dislike of ambiguity, were included as predictors. Under the demands of higher workload, the working memory factors became more important as predictors of strategy selection. For instance, under higher workload conditions, individuals may choose to use strategies that reduce their cognitive load.

In order to determine whether differences based on strategy selection existed among cognitive individual difference factors, a series of ANOVAs were conducted. As in the Easy condition, we compared strategies using cognitive individual difference factors as the dependent variables. Table 19 shows mean standardized scores for each of the predictors in the Difficult Condition by type of strategy used, and F-values corresponding to the ANOVAs. Unlike the Easy condition, in the Difficult condition, two factors differed significantly from the others: OSPAN, $F(5, 27) = 2.54$, $p = .05$, and NFCS – Discomfort in Ambiguity subscale, $F(5, 27) = 2.81$, $p < .05$. *Fisher's LSD* post-hoc tests showed that, in terms of OSPAN, individuals who self-reported Focus 2 (focus on two tasks) differed from those that reported using a unique Strategy (Focus 6). Individuals who reported using Focus 6 had a larger mean OSPAN than those that used Focus 2. This is especially interesting given that Focus 6 was a category consisting of a variety of unique strategies, many of which were not well defined. According to these data, participants with lower OSPANs used better-defined strategies. Given that Focus 2 consisted of focusing on two of the four tasks, these participants may not have had sufficient cognitive resources to "multitask," or spread their attention. Instead, they focused their attention on a limited number of tasks. *Fisher's LSD* post-hoc tests showed that, in terms of OSPAN, individuals who used Focus 3 (attending to three of the four tasks) differed from those who used Focus 4 (equal time spent on all four tasks). Individuals who used Focus 3 ignored one task almost completely, whereas those who used Focus 4 attempted to spread their attention equally among the four tasks. Interestingly, those that used Focus 3 scored higher on OSPAN than did those who used Focus 4. The use of Focus 3 may have served to free up cognitive resources to use on the remaining three tasks. Moreover, focusing on fewer stimuli may have enabled these individuals to focus their attention on what they considered to be more important stimuli.

The NFCS Dislike in Ambiguity subscale also produced significant differences among strategies. *Fisher's LSD* post-hoc tests showed that individuals who used Focus 1 (focus on one task) differed significantly from those using Focuses 2 (focus on two tasks) and 3 (focus on three tasks, ignore one). Those individuals who scored higher on the Dislike in Ambiguity subscale were more likely to use Focus 1 than either of the other two strategies. In Focus 1, the individual's main focus is on one task. Individuals with a high dislike of ambiguity may have chosen to focus on the one task, in an attempt to create structure in the dynamic environment. By limiting his or her activity in the multitasking environment, an individual may feel more in control over the dynamic environment, decreasing ambiguity. *Fisher's LSD* post hoc tests also showed that individuals who selected Focuses 2 and 3 differed significantly from those that selected Focuses 4 (equal time on all 4 tasks) and 5 (equal time on 2 tasks, equal time on 2 tasks) in terms of Dislike of Ambiguity (Focuses 2 and 3 did not differ from one another). Individuals who used Focuses 4 and 5 scored higher on Dislike of Ambiguity than did individuals using Focuses 2 and 3. Again, this difference may be an attempt by the individual to limit ambiguity in his or her environment by limiting the number of tasks being attended to at once.

These results indicated two main findings. First, under low workload conditions, strategy selection is guided by one's comfort with situational ambiguity. The <u>only</u> predictors of strategy selection in the Easy condition were the Need for Closure Scale and its subscales. Thus, when workload is low, a cognitive preference, rather than a cognitive restriction (e.g., processing capacity), determined which strategy would be used. Second, under conditions of high workload, strategy selection is predicted by WM factors of operation span and executive function in addition to comfort with ambiguity. For example, one's OSPAN score predicted which strategy would be used: those with lower OSPAN scores used strategies that required them to allocate attention simultaneously to a number of tasks. As Bleckley et al. showed, those with lower OSPAN scores performed worse on that type of tasks than those with higher scores on OSPAN. Thus, these individuals may have been using an inefficient strategy.

General Discussion

In two experiments, we attempted to address two questions: whether cognitive individual differences predict strategy selection in a future memory task, and whether an objective measure could be identified that corroborated individual self-reports of strategy selection. Consistent with predictions, the studies showed that cognitive individual differences predicted individual strategy selection. In Experiment 1, we found that field dependence/independence, need for closure, and executive control capability (as measured by the WCST) predicted strategy choice at a moderate workload level. Score on OSPAN was *not* a significant predictor of strategy selection, although it differed by strategy. Experiment 2 showed that cognitive individual differences differentially predicted strategy selection under conditions of low and high workload. Under low workload conditions ("Easy" condition), need for closure was the only predictor of strategy type. Under high workload conditions, however, OSPAN and executive control ability (measured using WCST) predicted strategy along with Need for Closure. These results suggested that with sufficient cognitive resources to perform the Synwork1 task, participants' comfort with situational ambiguity determined which strategy they selected. However, when an individual's cognitive resources were taxed, strategies became dependent on WM capacities and processing ability. Thus, one's strategy preference is dependent upon workload level, and is predicted by their cognitive abilities.

Under demands of higher workload, working memory factors became more important as predictors of strategy selection. This suggests that under higher workload conditions, individuals may choose to use strategies that reduce their cognitive load. McNamara and Scott (2001) found that operators that strategically reduced the amount of material to be processed used fewer cognitive resources than normally required to perform the same task. In Experiment 2, one strategy was used by a greater proportion of participants in the Difficult workload condition than in the Easy condition. The number of participants that reported spending an equal amount of time focused on the four tasks increased by 12% from the Easy condition, and the pattern of transitions indicated that participants actively attempted to reduce their workload by making a single response in each task before moving to the next task.

Similarly, participants with lower OSPANs used better-defined strategies overall. By adding structure onto the task, effectively reducing workload, individuals with lower OSPANs had less information to process and to remember. Therefore, low-OSPAN individuals may have strategically used better-defined strategies in an attempt to improve performance. For instance, individuals with lower OSPAN used Focus 2 (focus on two tasks), which reduced the amount of information to process. This finding lends support to Damos and Smist's (1982) suggestion that differences in the way individuals process information determines which strategy they used.

The present results were consistent with those from a series of studies conducted by Schunn and Reder (2001), which suggested that strategy adaptivity was a source of individual differences and that these differences were based on WM capacity. In their series of studies, however, Schunn and Reder used dependent measures of WM capacity (or span). Engle argued that these differ importantly from the operation span test used in the present studies. As discussed previously, the operation span test measures not only WM span, but also central executive functioning. This difference may also explain why in another study, Schunn, Lovett, and Reder (2001) found no relationship between WM span and strategy adaptivity. The present results suggest that more than simple WM span would be utilized in strategy adaptivity. Other cognitive individual difference factors may be involved as well. In Experiment 2, central executive function as measured by the WCST was found to be an important factor in determining individual strategy choice. However, this speculation does not adequately address McNamara and Scott's (2001) suggestion that performance on WM tasks improves when strategies are used because strategies free up cognitive resources, creating more efficient storage in WM. If strategic choice/adaptivity is due to central executive function, then more efficient <u>storage</u> should not be the answer. Indeed, future studies must be conducted in which measures of both WM capacity and central executive function are measured to see where the relationship exists.

The studies presented here also provided insight into cognitive factors that underlie strategy selection and adaptivity. Studies in these areas are especially complex as the type of environment in which the operator works is generally dynamic and fast, making data collection and analysis difficult at best. However, the analyses presented here add a new dimension to the literature on strategy selection. Analyses of proportion of time spent in each task and proportion of responses made in each task corroborated participants' self-reported strategy choice. Because participants were able to report their own strategies, experimenter biases were reduced. Moreover, the Pathfinder networks presented here provided the reader with a visual representation of the strategies used, thereby enabling the reader to visualize the strategies much as the operators employed them. This method differs considerably from methods used in previous studies on strategies, where strategic performance has generally been measured in terms of overall score or percent correct (e.g., Schunn, Lovett, & Reder, 2001; Schunn & Reder, 2001). Analyzing overall score or percent correct is an inadequate method of analyzing a participants' strategy. For instance, two participants may receive a similar final score, but may have used very different means to arrive at the score. A clear example of this can be seen in the Pathfinder networks for Focus 1 and Focus 4 in Experiment 2. Clearly, these two networks differed in terms of the proportion of responses made in each task (node size), as well as in the types of transitions among tasks that were made. However, their final scores of 6149 and 6347 were quite similar. Thus, further investigation of the utility of the three methods presented here for analyzing strategic selection in multitasking is warranted. By examining these three methods in a variety of future memory environments, researchers will gain further insight into the influence of cognitive individual differences on strategy selection.

A limitation of the present study lies in its inability to account for participants' attention at all times. In the Synwork1 environment, it is possible for an individual to attend to one task while simultaneously performing another task (e.g., complete math problems while monitoring the visual monitoring bar in peripheral vision), or for a participant to actually attend to one task for a greater amount of time (or number of responses, etc.) than is actually demonstrable from the collected data. For instance, an individual may spend a large amount of time attending to the Sternberg task, and directing the computer's mouse to that task (holding the mouse in the quadrant), but responding only when necessary (i.e., not making unnecessary responses). This might result in the participant correctly reporting that he or she attended more to one quadrant than another, yet the objective data would not support this assertion. An improvement on this design would incorporate an eye-tracking device, which would provide supporting evidence for the location of a participant's attention throughout the trial. By including an eye tracker, the researcher would be able to account for an individual's visual attention throughout the trial, which would provide further support for the individuals' subjective reports of strategy use.

The studies presented here showed that cognitive individual differences affect the strategies that individuals select in future memory tasks. The example of the air traffic controller has been used throughout this work, but pilots, nurses, physicians, and secretaries each deal with future memory tasks everyday. Accordingly, for some positions, it may be useful to develop a selection instrument that would be used to select a particular cognitive individual difference "type," and not select others. For instance, an air traffic controller with a high OSPAN score would probably be a good fit; he or she would have a great deal of resources to work on a highly demanding job. In comparison, an individual with a high need for closure may not be as good a fit as an air traffic controller. Under demanding conditions (e.g., planes rerouted into the sector), would this controller break down, causing errors? Cognitive individual differences should be considered as useful tools in selecting appropriate employees for particular positions.

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Table 1

Synwork1 Dependent Variables and Descriptions

Overall Task

Composite Score – overall Synwork1 score
Overall Response Rate – overall rate to respond to stimuli (in seconds)

Sternberg Task

Score – score on task
Response Rate – rate to respond to Sternberg stimuli (in msec)
Percent Errors - overall percent of stimuli incorrectly identified
Percent Omissions – Number of times participants failed to respond to a stimulus
Percent Correct - overall percent of stimuli correctly identified
Number of List Retrievals – Number of times participants retrieved list to verify an answer

Math Task

Score – score on task
Response Rate – rate to respond to Math problem (in msec)
Number of Problems Completed – overall number of problems completed
Percent Correct – overall percent of problems solved correctly
Number of increments – Number of times the + button was used to increment sum
Number of decrements – Number of times the - button was used to decrement sum

Visual Monitoring

Score – score on task
Response Rate – rate to respond to Visual Monitoring stimuli (in msec)
Average Distance From Center – Distance that the moving bar traveled from the center
Inter-Reset Interval – Amount of time to reset bar
Number of Lapses – Number of times bar reached the end

Auditory Monitoring

Score – score on task
Response Rate – rate to respond to Auditory Monitoring stimuli (in msec)
Positive Tone Detections – Responded appropriately to a high tone
False Alarms – Responded inappropriately to a high tone
Quiets – Failed to respond to a high tone
Misses – Responded incorrectly to a high tone
Percent Signals Detected – overall percent of signals correctly detected

Table 2

Ranges and Mean Values of Cognitive Individual Difference Factors

	Min	Max	Mean	SD
GEFT	4	18	11.77	4.42
OSPAN	5	45	13.35	7.71
WCST – Percent correct	46.09	86.52	73.54	12.87
WCST- Percent persev. Errors	7.87	30.47	13.53	6.15
WCST – Learning to learn	-56.84	33.77	-7.29	23.99
NFCS – Total	123	191	144.8	14.31
NFCS – Order	30	48	37.4	5.14
NFCS – Predictability	19	38	25.63	4.54
NFCS – D	14	30	23.87	5.70
NFCS – Ambiguity	25	41	32.27	3.86
NFCS - C	16	35	23.67	3.98

Table 3

Correlations Among Cognitive Individual Difference Variables

	GEFT	OSPAN	WCST % corr	WCST % persev errors	WCST Learning to learn	NFCS total	NFCS order	NFCS Predict.	NFCS Decisiveness	NFCS Ambiguity	NFCS Closedmind
GEFT	–										
OSPAN	32	–									
WCST % corr	30	-24	–								
WCST % pers. Errors	-16	-23	-88**	–							
WCST Learn. to learn	37*	05	45*	-29	–						
NFCS total	04	08	04	15	03	–					
NFCS order	15	22	-05	20	09	74**	–				
NFCS predict.	19	-18	22	-01	12	77**	50**	–			
NFCS decisive	14	01	12	-07	13	23	-03	-03	–		
NFCS Ambig.	-19	09	-05	18	-05	62**	18	46*	04	–	
NFCS closed-mind	-24	01	-12	18	-25	69**	27	47**	-01	55**	–

* $p < .05$. **$p < .01$

Table 4

Mean Performance on Synwork1 and t-value for Comparisons Between Days 2 and 3

	Mean	SD	*t* value
Comprehensive Score	4543.29	455.13	-3.39 *
Overall Response Rate	1.39	0.52	-0.91
Sternberg Task			
Score	870.65	312.77	-1.89 *
Response Rate	211.50	41.43	1.11
Percent Errors	11.46	11.49	2.57 *
Percent Omissions	3.71	17.96	-0.22
Overall Percent Correct	85.32	19.45	-0.03
List Retrievals	1.13	1.48	1.43
Math Task			
Score	1125.81	324.09	-2.42
Response Rate	731.31	164.63	-1.19
Number of Problems	141.35	39.69	-1.71 *
Overall Percent Correct	87.09	16.54	-1.79 *
Number of increments	1259.39	579.35	-0.67
Number of decrements	257.06	190.52	-1.22
Visual Monitoring Task			
Score	1799.42	570.51	0.76
Response Rate	264.66	79.83	0.52
Average Distance from Center	74.35	19.06	0.13
Number of Resets	7.65	1.99	0.15
Number of Lapses	3.58	5.31	0.35
Auditory Monitoring Task			
Score	844.19	56.49	0.25
Response Rate	590.82	120.46	1.00
Correct Detections	83.45	14.86	-0.29
False Alarms	1.61	1.63	1.49
Quiets	507.48	1.52	0.96
Missed Signals	3.94	4.99	1.15
Percent Signals Detected	95.66	5.58	-1.14

* $p < .05$

Table 5

Descriptions of Strategy Types and the Proportion of Participants Selecting Each Strategy

	Description of Strategy Used	Proportion Using Strategy
Focus 1	Focused on one task and only responded to others as necessary	.32
Focus 2	Focused on two tasks and only responded to the other two when necessary	.26
Focus 3	Focused on three tasks and only responded to the other one when necessary	.19
Focus 4	Spent an equal amount of time focused on all four tasks	.23

Table 6

Predictors of Strategy Selection Using Cognitive Individual Difference Variables

Parameter	Standard Estimate	Error	Wald Chi-Square	P> Chi-Square
GEFT	1.39	0.55	6.53	0.01*
OSPAN	-0.94	0.56	2.01	0.16
WCST – RT	-2.07	0.76	7.47	0.01*
WCST – PPE	-2.85	1.23	2.52	0.11
WCST - % C	-1.80	0.70	6.56	0.01*
WCST – L2L	0.48	0.51	0.87	0.35
NFC – total	18.96	7.78	5.94	0.01*
NFC – order	-7.97	3.29	5.86	0.02*
NFC – predictability	-6.13	2.42	6.39	0.01*
NFC – decisiveness	-8.39	3.23	6.78	0.01*
NFC – ambiguity	-5.49	2.10	6.82	0.01*
NFC - closedmindedness	-4.43	2.14	4.26	0.04*

* $p<.05$

Table 7

Mean Standardized Scores by Strategy Type

	Focus			
	1	2	3	4
GEFT	.18	.16	-.08	-.34
OSPAN	-.22	.75	-.21	-.36
WCST – RT	-.19	-.06	.10	.22
WCST - PPE	.16	-.01	.27	-.46
WCST - %C	-.24	-.02	-.08	.42
WCST – L2L	-.34	.35	.09	-.05
NFC - total	-.08	-.01	.18	-.08
NFC – preference for order	.07	.04	-.11	-.05
NFC – pref for predictability	-.07	-.06	.30	-.18
NFC – decisiveness	-.41	.09	-.00	.49
NFC – dislike of ambiguity	-.24	-.07	.45	-.07
NFC – closedminded-ness	.14	-.07	.19	-.34

Table 8

Ranges and Mean Values of Cognitive Individual Difference Factors

	Min	Max	Mean	SD
GEFT	2	18	12.64	5.02
OSPAN	4	29	12.38	6.26
WCST – Percent correct	28.91	91.43	70.61	16.61
WCST- Percent persev. Errors	4.76	38.28	14.88	8.97
WCST – Learning to learn	-70.52	27.75	-10.80	23.01
NFCS – Total	108	144	109.83	47.96
NFCS – Order	23	37	25.46	11.32
NFCS – Predictability	19	28	20.05	8.79
NFCS – D	15	25	16.93	7.81
NFCS – Ambiguity	24	38	25.93	11.84
NFCS - C	19	29	20.85	9.24

Table 9

Correlations Among Cognitive Individual Difference Variables

	GEFT	OSPAN	WCST % corr	WCST % persev errors	WCST Learning to learn	NFCS total	NFCS order	NFCS Predict.	NFCS Decisiveness	NFCS Ambiguity	NFCS Close dmind
GEFT	–										
OSPAN	.10	–									
WCST % corr	.22	.10	–								
WCST % pers. Errors	-.28*	-.10	-.88**	–							
WCST Learn. to learn	.04	.14	.51**	-.50**	–						
NFCS total	-.34**	-.01	.17	-.20	.01	–					
NFCS order	-.25*	-.26*	.17	-.09	-.02	.61**	–				
NFCS predict.	-.13	.13	-.00	-.00	.07	.53**	.23	–			
NFCS decisive	-.23	.12	-.05	.02	-.21	.58**	.14	.18	–		
NFCS Ambig.	-.15	.06	.21	-.21	.26*	.77**	.41**	.45**	.29*	–	
NFCS closed-mind	-.29*	.00	.18	-.29*	-.16	.55**	.15	.11	.16	.29*	–

* *p* < .05, ***p*<.01

Table 10

Synwork1 Variables by Condition and Dependent t-tests Comparing Easy and Difficult Conditions

	Easy Condition		*Difficult Condition*		
	Mean	*SD*	Mean	*SD*	*t*
Comprehensive Score	4561.30	937.17	7026.52	1165.56	
Overall Response Rate	1.34	0.49	1.45	0.61	
Sternberg Task					
Score	862.73	333.49	3186.36	4874.66	
Response Rate	186.01	52.22	445.94	99.30	
Percent Errors	11.16	11.33	8.61	6.26	1.13
Percent Omissions	4.49	18.05	15.96	19.86	-2.46
Overall Percent Correct	85.28	19.42	87.73	11.27	-0.63
List Retrievals	1.18	1.33	1.64	1.99	
Math Task					
Score	1162.42	640.77	1082.30	3084.93	0.15
Response Rate	700.24	261.15	317.36	198.77	6.70*
Number of Problems	143.70	69.65	78.85	52.32	4.28*
Overall Percent Correct	89.38	8.21	81.47	18.58	2.24
Number of increments	1129.06	558.16	657.09	445.07	3.79*
Number of decrements	348.30	249.16	179.45	168.91	3.22*
Visual Monitoring Task					
Score	1696.76	173.83	1706.03	2957.51	
Response Rate	273.97	81.17	295.69	210.11	
Average Distance from Center	89.09	119.66	277.43	623.80	-1.70
Number of Resets	7.21	2.09	5.62	2.07	
Number of Lapses	2.97	3.48	6.69	7.66	
Auditory Monitoring Task					
Score	839.39	110.48	1867.27	293.59	
Response Rate	612.52	189.73	736.74	148.74	
Correct Detections	85.09	9.97	195.67	24.78	
False Alarms	1.15	1.73	8.94	7.27	
Quiets	500.15	45.11	666.42	6.98	
Missed Signals	3.52	5.82	29.12	24.75	
Percent Signals Detected	95.89	6.58	87.01	11.00	3.98*

* $p < .0045$

Table 11

Descriptions of the Six Self-Reported Strategy Types and the Proportion of Participants Selecting Each Strategy in Easy and Difficult Conditions

	Description of Strategy Used	Proportion Using Strategy	
		Easy	Difficult
Focus 1	Focused on one task and only responded to others as necessary	.39	.18
Focus 2	Focused on two tasks and only responded to the other two when necessary	.24	.24
Focus 3	Focused on three tasks and only responded to the other one when necessary	.03	.09
Focus 4	Spent an equal amount of time focused on two tasks, and an equal amount of time focused on the other two tasks	.03	.09
Focus 5	Spent an equal amount of time focused on all four tasks	.15	.27
Focus 6	Devised own strategy	.18	.09

Table 12

Proportion of Time in Synwork1 Tasks in Easy and Difficult Conditions

Easy Condition

Task	1	2	3	4	5	6	*Mean*
Stem	.10	.11	.11	.13	.01	.11	.10
Math	.43	.36	.26	.48	.44	.29	.38
AM	.14	.17	.12	.01	.17	.16	.13
VM	.32	.36	.51	.29	.30	.43	.37
Mean	.25	.25	.25	.23	.23	.25	.25

Difficult Condition

Task	1	2	3	4	5	6	*Mean*
Stem	.22	.25	.22	.25	.26	.28	.25
Math	.18	.24	.11	.24	.19	.01	.16
AM	.22	.11	.29	.13	.14	.14	.17
VM	.38	.40	.38	.38	.41	.51	.41
Mean	.25	.25	.25	.25	.25	.24	.25

Table 13

Proportion of time in tasks in Easy and Difficult Conditions by individual participants (participant number in subscripts).

		Easy Condition		
Focus	Stem	Math	VM	AM
1_{40}	.08	.61	.13	.18
2_{28}	.12	.25	.25	.38
3_{32}	.11	.26	.12	.51
4_{30}	.13	.48	.10	.29
5_{52}	.14	.28	.23	.35
6_{26}	.06	.55	.13	.27

		Difficult Condition		
Focus	Stem	Math	VM	AM
1_{18}	.10	.12	.57	.21
2_{28}	.19	.25	.16	.40
3_{58}	.35	.00	.09	.55
4_{47}	.31	.13	.11	.44
5_{23}	.25	.04	.21	.49
6_{62}	.28	.00	.20	.51

Table 14

Proportion of Responses in Synwork1 Tasks in Easy and Difficult Conditions

Easy Condition

Task	1	2	3	4	5	6	*Mean*
Stern	.01	.01	.01	.01	.01	.01	.01
Math	.75	.73	.69	.81	.77	.65	.73
AM	.00	.00	.01	.00	.00	.01	.00
VM	.14	.16	.15	.01	.15	.21	.14
Mean	.23	.23	.22	.21	.23	.22	.22

Difficult Condition

Task	1	2	3	4	5	6	*Mean*
Stern	.17	.15	.17	.16	.19	.29	.19
Math	.41	.58	.25	.56	.52	.22	.42
AM	.11	.10	.13	.11	.12	.18	.13
VM	.31	.16	.46	.18	.22	.32	.28
Mean	.25	.25	.25	.25	.26	.25	.26

Table 15

Proportions of responses in tasks in Easy and Difficult Conditions by individual participants (participant number in subscripts).

		Easy Condition		
Focus	Stem	Math	VM	AM
1_{40}	.03	.87	.02	.07
2_{28}	.05	.66	.05	.24
3_{32}	.09	.69	.07	.15
4_{30}	.06	.81	.04	.09
5_{52}	.06	.64	.03	.27
6_{26}	0	.87	.04	.09

		Difficult Condition		
Focus	Stem	Math	VM	AM
1_{18}	.04	.19	.06	.72
2_{28}	.09	.61	.10	.20
3_{58}	.42	.02	.26	.30
4_{47}	.24	.44	.13	.19
5_{23}	.28	.16	.18	.39
6_{62}	.30	0	.19	.50

Table 16

Predictors of Strategy Use in Easy Condition

Parameter	Standard Estimate	Error	Wald Chi-Square	P> Chi-Square
GEFT	-0.29	0.61	0.14	0.70
OSPAN	0.67	0.49	2.86	0.09
WCST PPE	-1.44	1.42	1.20	0.27
WCST %C	-0.72	1.41	0.78	0.85
WCST L2L	-0.21	0.65	0.11	0.75
NFC – total	-36.22	17.01	4.53	0.03*
NFC – order	9.76	4.74	4.24	0.04*
NFC – predictability	8.27	4.07	4.13	0.04*
NFC – decisiveness	7.71	3.06	6.34	0.01*
NFC – ambiguity	8.50	3.89	4.77	0.03*
NFC - closedmindedness	8.97	4.15	4.66	0.03*

* *p<.05*

Table 17

Mean Standardized Scores in Easy Condition by Strategy Type

	Focus					
	1	2	3	4	5	6
GEFT	-0.05	-0.75	-1.12	0.47	0.47	0.63
OSPAN	0.41	0.47	0.10	-1.02	-0.06	-0.06
WCST PPE	-0.18	-0.04	0.21	-0.70	0.19	0.18
WCST %C	-0.00	-0.09	0.00	0.70	-0.30	-0.07
WCST L2L	-0.11	0.25	1.10	1.68	-0.44	0.68
NFC - total	0.42	0.38	0.55	0.42	0.34	0.27
NFC – preference for order	0.39	0.38	0.84	0.58	0.46	0.17
NFC – pref for predictability	0.46	0.43	0.34	0.34	0.34	0.45
NFC – decisiveness	0.52	0.28	0.65	-0.25	0.05	0.32
NFC – dislike of ambiguity	0.41	0.34	0.43	0.68	0.33	0.21
NFC – closedminded-ness	0.37	0.40	0.23	0.56	0.41	0.15

* *p<.05*

Table 18

Predictors of Strategy Use in Difficult Condition

Parameter	Standard Estimate	Error	Wald Chi-Square	P> Chi-Square
GEFT	0.73	0.51	1.21	0.27
OSPAN	-1.18	0.45	6.76	0.01*
WCST % Perseverative Errors	-3.38	1.36	6.14	0.01*
WCST % Correct	-2.41	1.22	3.92	0.05*
WCST L2L	0.69	0.61	1.76	0.18
NFC – total	-15.08	4.95	9.30	0.00*
NFC – order	2.15	4.70	1.51	0.22
NFC - predictability	4.10	3.72	3.31	0.07
NFC – decisiveness	5.96	1.86	10.28	0.00*
NFC –ambiguity	5.18	2.13	5.90	0.02*
NFC - Closedmindedness	-0.87	4.32	0.04	0.84

* $p<.05$

Table 19

Mean Standardized Scores in Difficult Condition by Strategy Type

	Focus					
	1	2	3	4	5	6
GEFT	0.57	-0.47	0.67	-0.01	-0.30	-0.38
OSPAN	0.18	0.20	0.58	-0.86	-0.04	1.22
WCST % Correct	0.33	-0.46	0.01	0.07	-0.10	-0.09
WCST % Persev. Errors	-0.56	0.23	-0.67	-0.08	0.25	-0.11
WCST L2L	0.58	-0.37	0.00	-0.00	0.47	-0.29
NFC – total	0.42	0.35	0.20	0.50	0.43	0.35
NFC - order	0.42	0.35	0.15	0.58	0.39	0.56
NFC -predictability	0.45	0.47	0.31	0.30	0.46	0.45
NFC – decisiveness	0.39	0.41	0.36	0.39	0.41	-0.12
NFC –ambiguity	0.57	0.22	0.01	0.54	0.47	0.32
NFC - closemindedness	0.25	0.29	0.36	0.56	0.35	0.42

Appendix

Post-Experiment Strategy Questionnaire

Describe how you performed the task today. Use the back of the page to make any comments.

Letter	Math
Bar	**Beep**

1. I focused on the __________ task and only responded to the other 3 tasks when I noticed something happening in one of them.

2. I focused on the __________ task and the __________ task and only responded to the other 2 tasks when I noticed something happening in one of them.

3. I ignored the __________ task altogether and focused equally on the other 3 tasks.

4. I spent an equal amount of time focused on the __________ and __________ tasks, and an equal amount of time focused on the __________ and __________ tasks.

5. I spent an equal amount of time focused on all four tasks.

6. I used a different strategy. (Describe it here.)

Figure Captions

Figure 1. Task analysis of Synwork1 Synthetic Work Environment.

Figure 2. The Synwork1 Task: Sternberg task is located in upper left quadrant, and the Math task in the upper right quadrant. Visual monitoring task is located in the lower left quadrant, and the auditory monitoring task in the lower right quadrant.

Figure 3. Pathfinder Networks of Participants using Focus 1 in Easy Condition (upper panel) and Focus 2 in Easy Condition (lower panel).

Figure 4. Pathfinder Networks of Participants using Focus 3 in Easy Condition (upper panel) and Focus 4 in Easy Condition (lower panel).

Figure 5. Pathfinder Networks of Participants using Focus 5 in Easy Condition (upper panel) and Focus 6 in Easy Condition (lower panel).

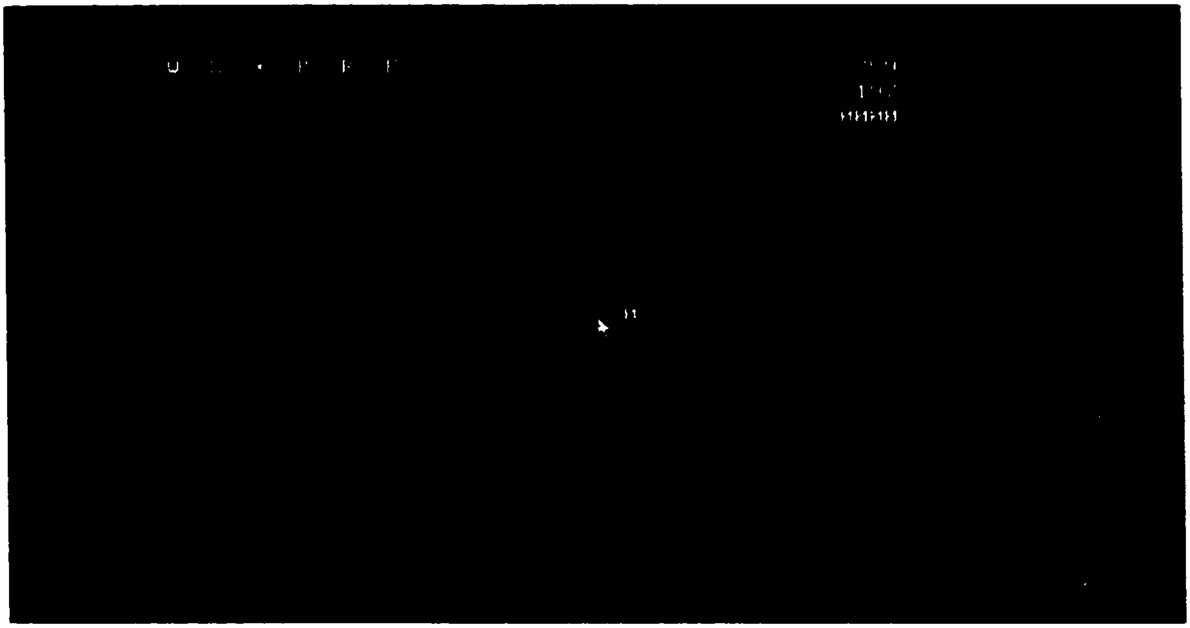
Figure 6. Pathfinder Networks of Participants using Focus 1 in Difficult Condition (upper panel) and Focus 2 in Difficult Condition (lower panel).

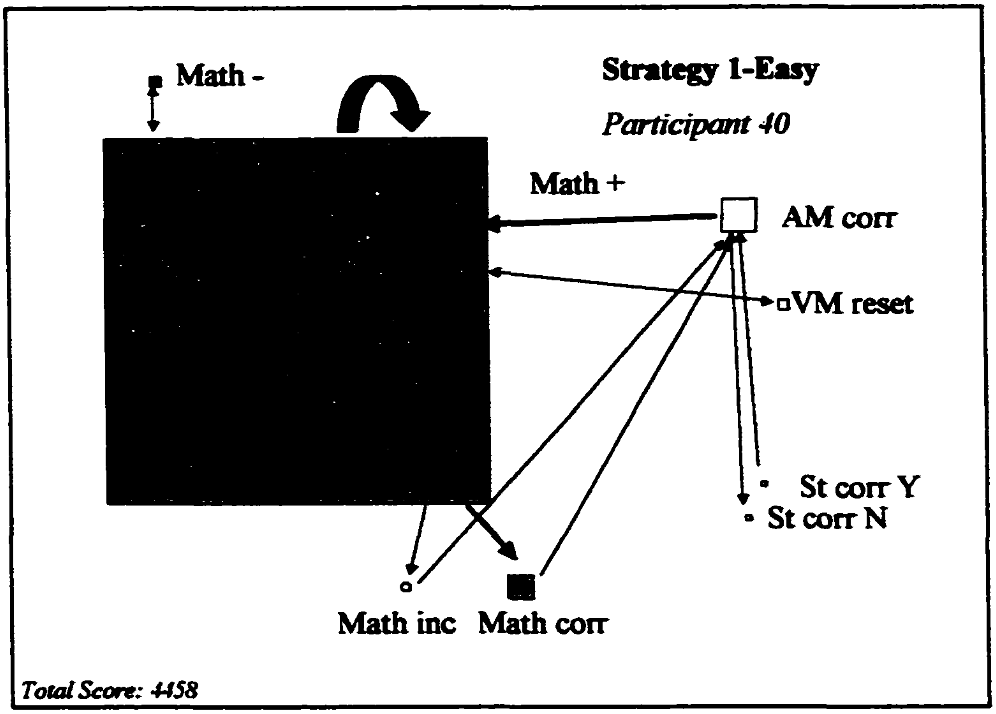
Figure 7. Pathfinder Networks of Participants using Focus 3 in Difficult Condition (upper panel) and Focus 4 in Difficult Condition (lower panel).

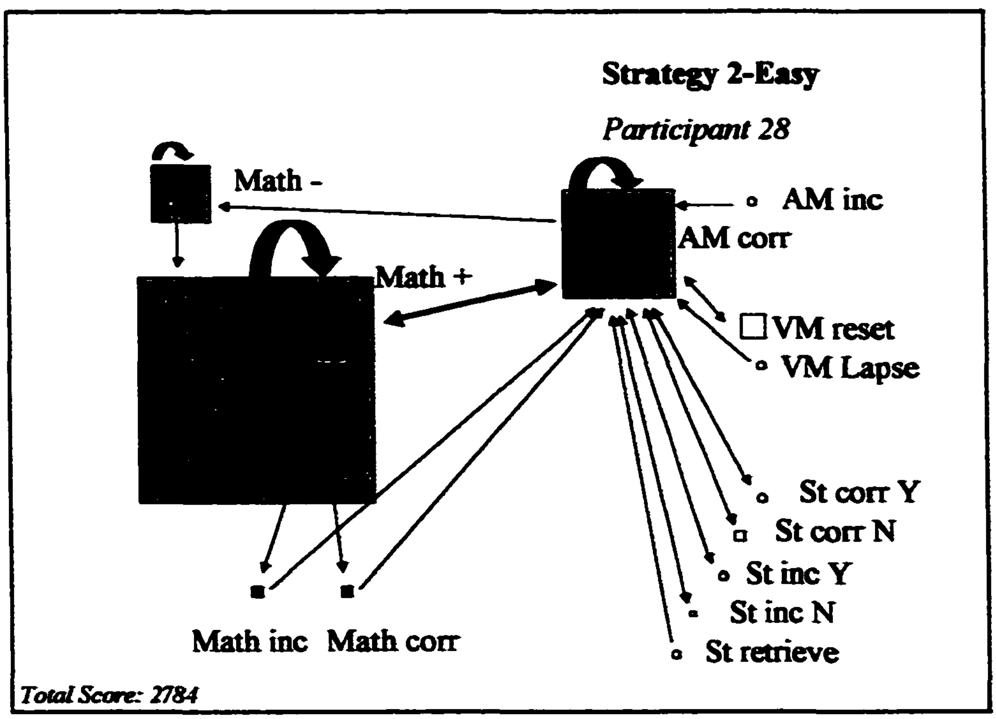
Figure 8. Pathfinder Networks of Participants using Focus 5 in Difficult Condition (upper panel) and Focus 6 in Difficult Condition (lower panel).

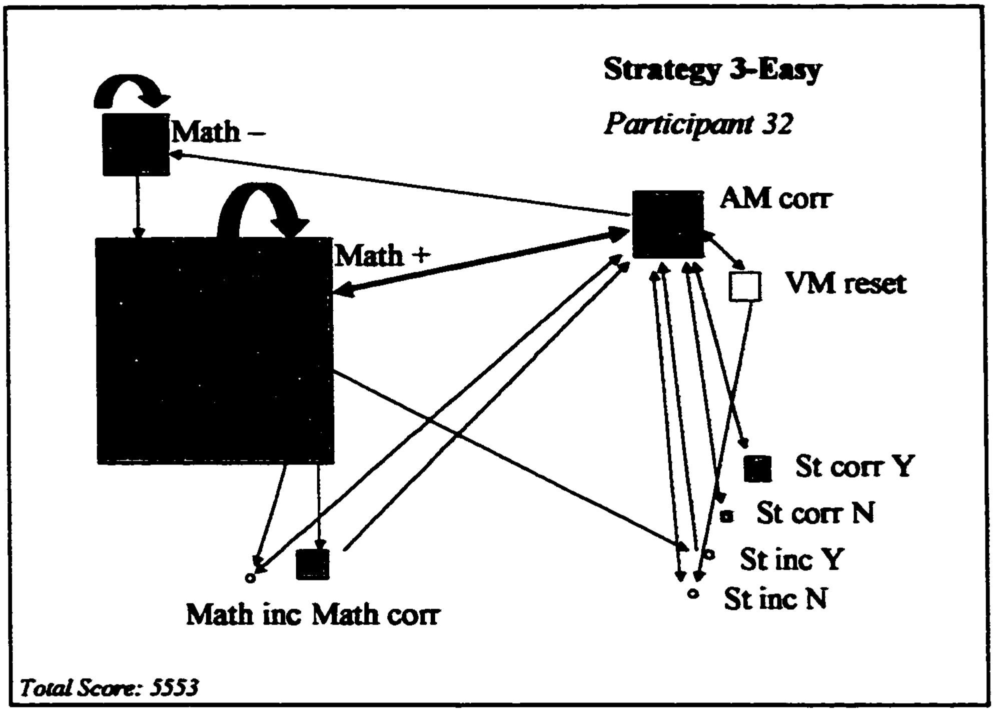
Figure 1. *Task analysis of Synwork1 Synthetic Work Environment.*

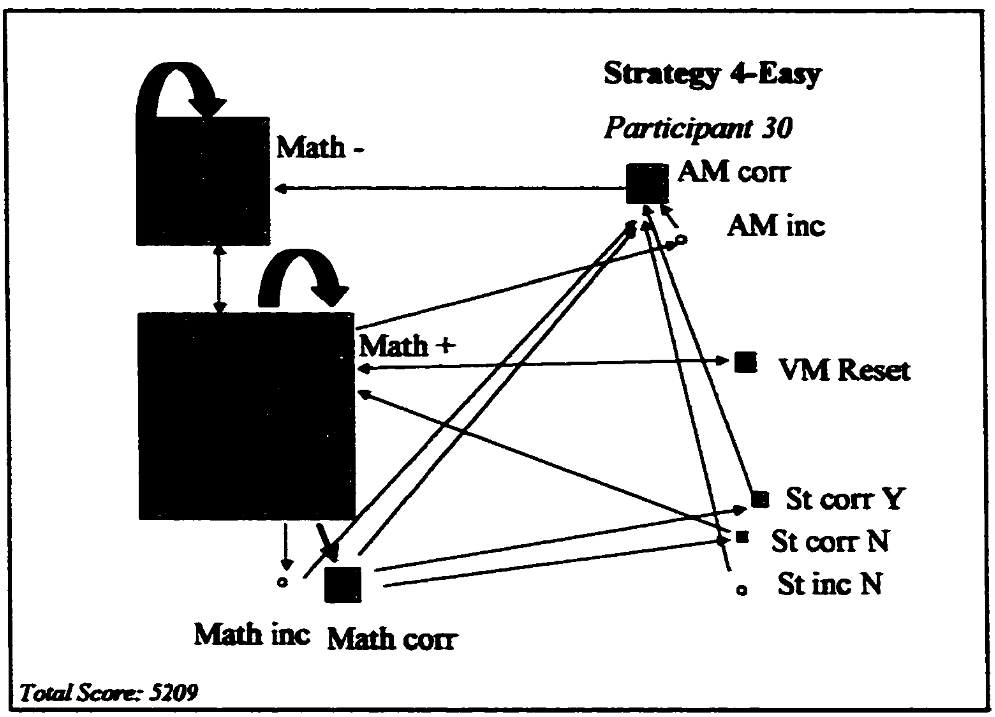
Task	Goal	Actions	Feedback	Potential Errors
Sternberg Task	Monitor and respond appropriately to presented stimuli	1. Memorize 6 letters presented at study 2. Monitor Sternberg quadrant for periodic presentation of letters 3. Respond appropriately to letters (i.e., select Y or N button depending on whether the stimuli were presented at study). 4. Retrieve list of 6 letters if necessary.	Points increased or decreased from Total score box in center of quadrants.	1. Incorrectly responding to stimuli (i.e., respond Y to a letter that was not presented, or vice versa). 2. Missing the presentation of the stimuli.
Math Task	Sum two, three-digit numbers	1. Mentally sum digits in the ones column (rightmost). 2. Increment or decrement the value using the + and – buttons located under the ones column. 3. Mentally sum digits in the tens column (center), including any remainder from ones column. 4. Increment or decrement the value using the + and – buttons located under the tens column. 5. Mentally sum digits in the hundreds column (leftmost), including any remainder from tens column. 6. Increment or decrement the value using the + and – buttons located under the hundreds column. 7. Select 'end' button.	Points increased or decreased from Total score box in center of quadrants.	1. Error in mental arithmetic. 2. Error in incrementing or decrementing sums.
Visual Monitoring	Monitor and respond appropriately to visual stimuli	1. Monitor sliding bar as it moves from the center of a line to the right or left. 2. As the bar approaches the end of the line, use the reset button to center the bar on the line. 3. If the bar reaches the end of the line, use the reset button to center the bar on the line.	Points increased or decreased from Total score box in center of quadrants.	1. Allowing the bar to reach the end of the line.
Auditory Monitoring	Monitor and respond appropriately to auditory stimuli	1. Monitor high and low tones as they are presented. 2. When a high tone is presented, select the "high tone" button.	Points increased or decreased from Total score box in center of quadrants.	1. Responding incorrectly to a high or low tone. 2. Missing the presentation of the stimuli

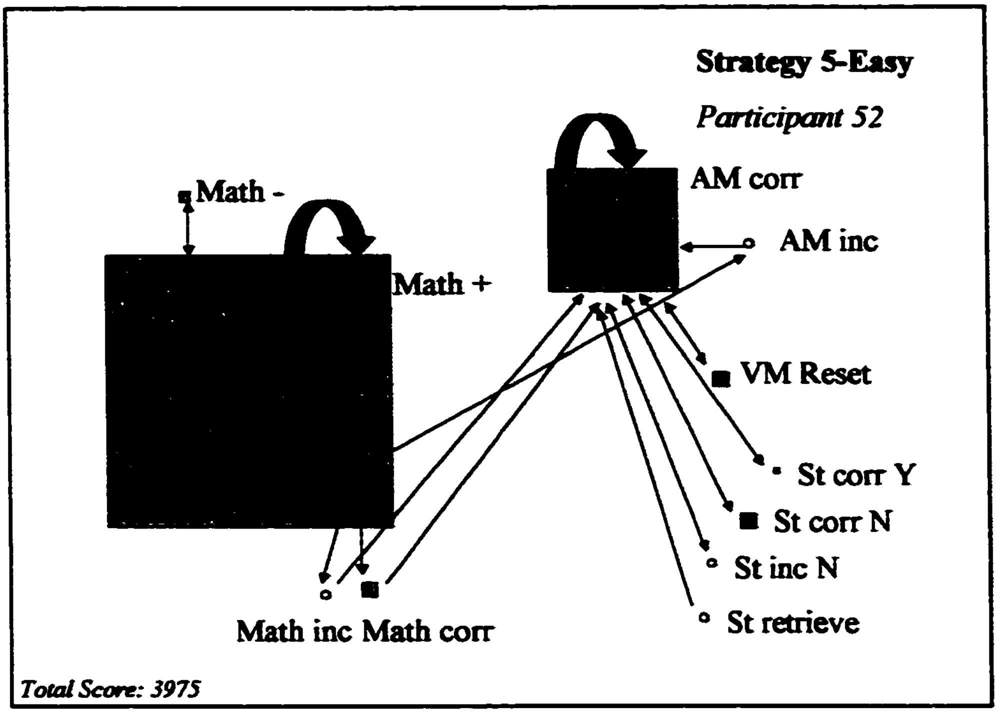


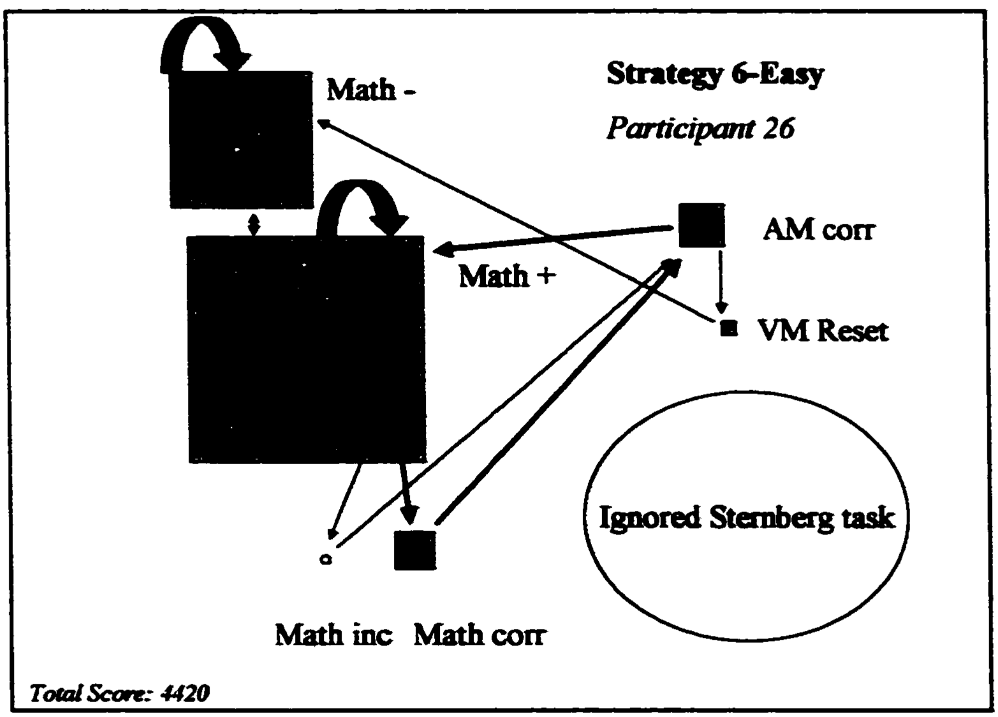

Strategy 1-Easy
Participant 40
Math -
Math +
AM corr
VM reset
St corr Y
St corr N
Math inc
Math corr
Total Score: 4458

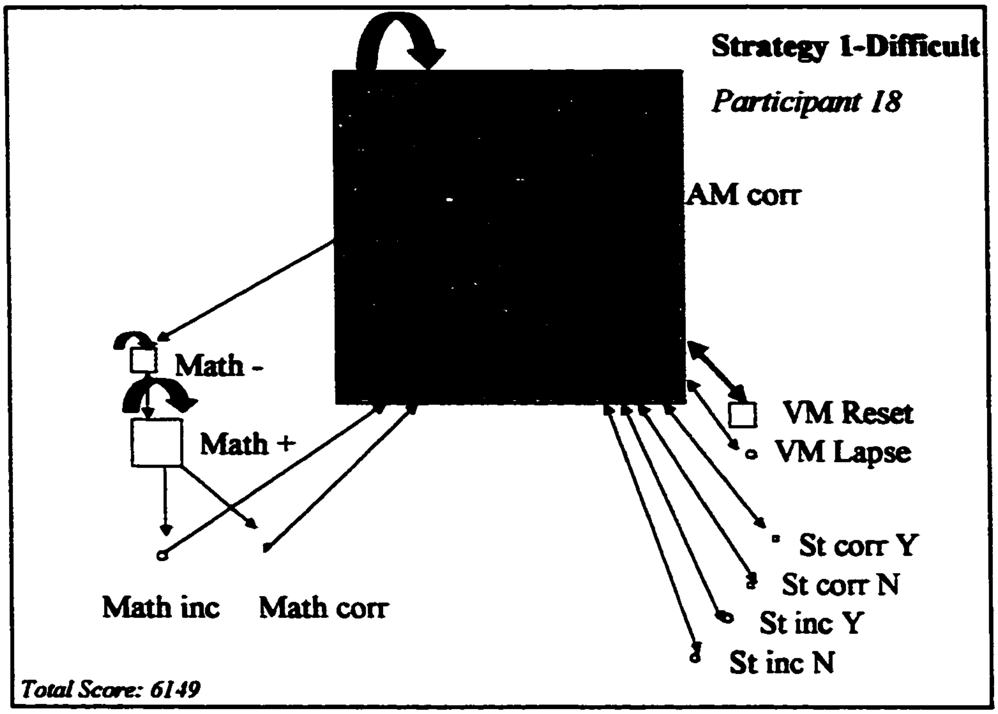

Strategy 2-Easy
Participant 28
Math -
AM inc
AM corr
Math +
VM reset
VM Lapse
St corr Y
St corr N
St inc Y
St inc N
St retrieve
Math inc
Math corr
Total Score: 2784

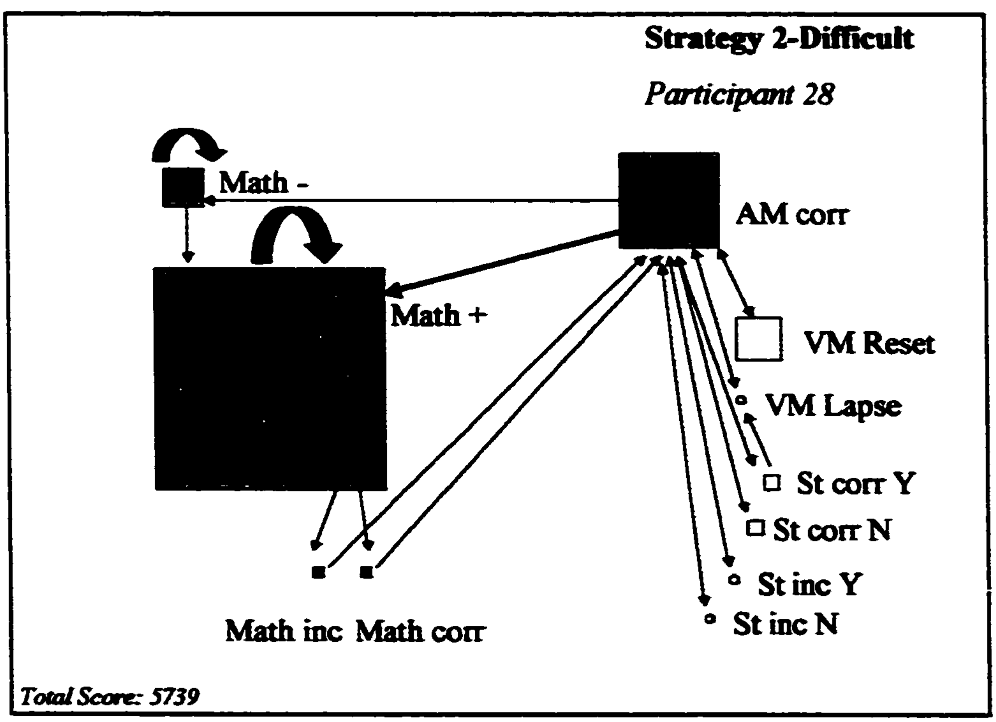

Strategy 3-Easy
Participant 32
Math –
AM corr
Math +
VM reset
St corr Y
St corr N
St inc Y
St inc N
Math inc Math corr
Total Score: 5553

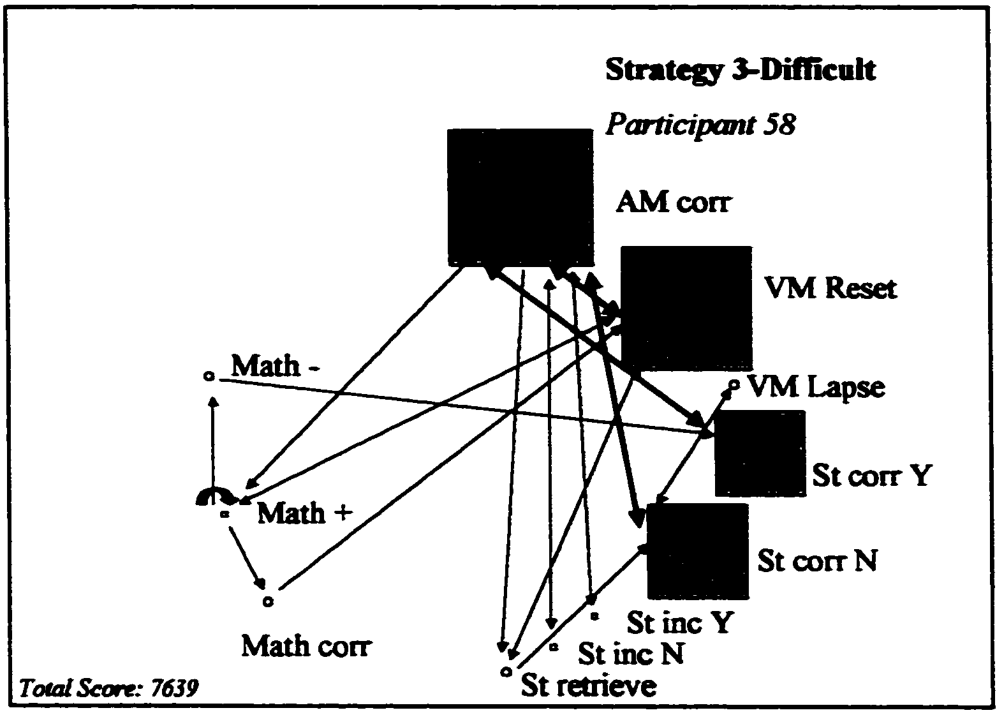

Strategy 4-Easy
Participant 30
Math -
AM corr
AM inc
Math +
VM Reset
St corr Y
St corr N
St inc N
Math inc Math corr
Total Score: 5209

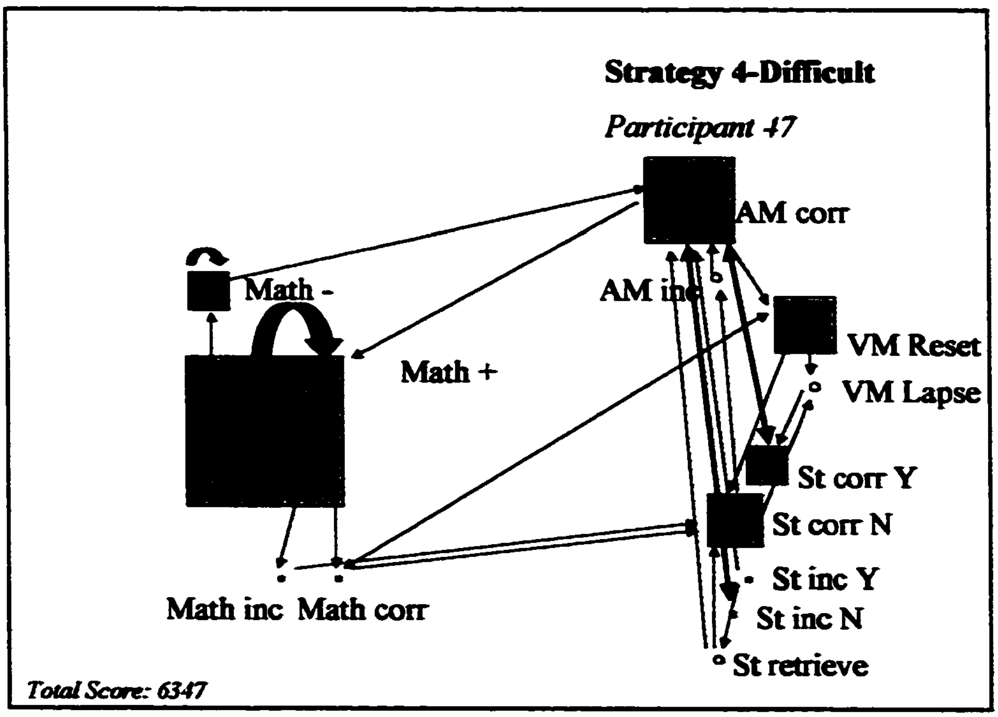

Strategy 5-Easy
Participant 52
AM corr
AM inc
Math -
Math +
VM Reset
St corr Y
St corr N
St inc N
St retrieve
Math inc Math corr
Total Score: 3975

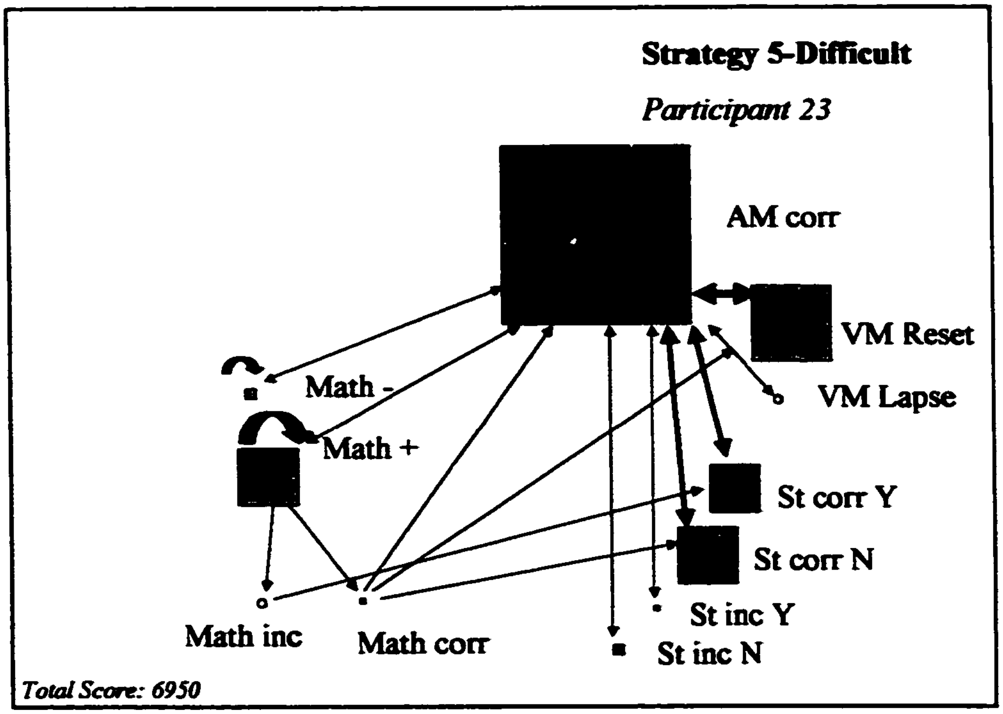

Math -
Strategy 6-Easy
Participant 26
AM corr
Math +
VM Reset
Ignored Sternberg task
Math inc Math corr
Total Score: 4420


Strategy 1-Difficult
Participant 18
AM corr
Math -
Math +
Math inc
Math corr
VM Reset
VM Lapse
St corr Y
St corr N
St inc Y
St inc N
Total Score: 6149

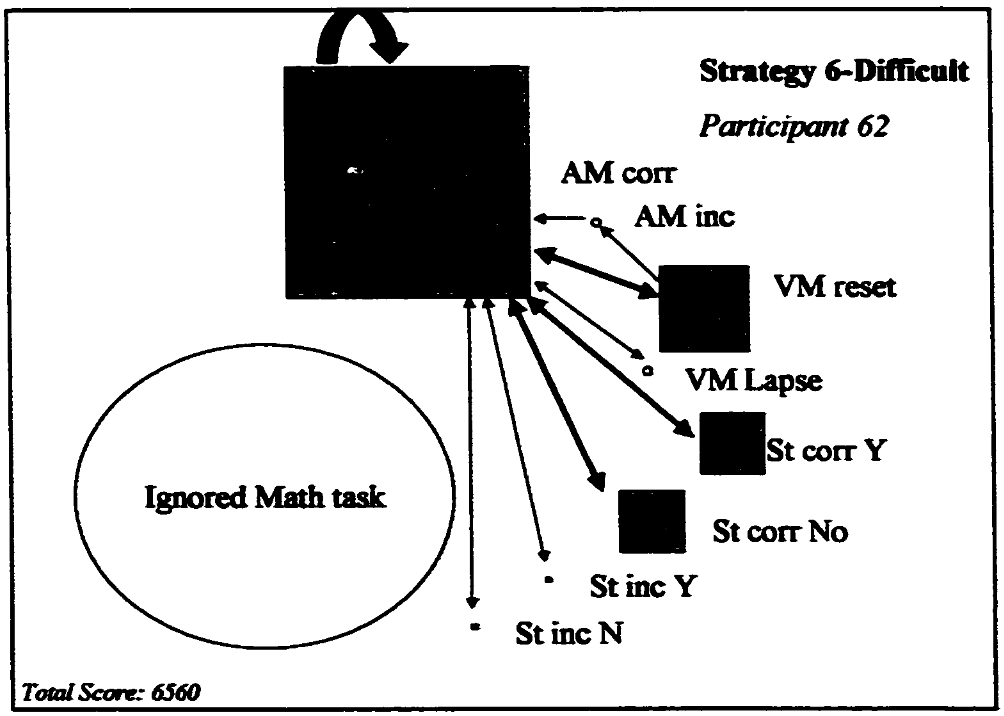

Strategy 2-Difficult
Participant 28
Math -
AM corr
Math +
VM Reset
VM Lapse
St corr Y
St corr N
St inc Y
St inc N
Math inc
Math corr
Total Score: 5739


Strategy 3-Difficult
Participant 58
AM corr
VM Reset
Math -
VM Lapse
St corr Y
Math +
St corr N
St inc Y
Math corr
St inc N
St retrieve
Total Score: 7639


Strategy 4-Difficult
Participant 47
AM corr
Math -
AM inc
Math +
VM Reset
VM Lapse
St corr Y
St corr N
St inc Y
Math inc
Math corr
St inc N
St retrieve
Total Score: 6347



Strategy 5-Difficult
Participant 23
AM corr
VM Reset
VM Lapse
Math -
Math +
St corr Y
St corr N
St inc Y
St inc N
Math inc
Math corr
Total Score: 6950



Strategy 6-Difficult
Participant 62
AM corr
AM inc
VM reset
VM Lapse
St corr Y
St corr No
St inc Y
St inc N
Ignored Math task
Total Score: 6560