UNIFIED TRI-SERVICE COGNITIVE PERFORMANCE ASSESSMENT BATTERY (UTC-PAB) I. DESIGN AND SPECIFICATION OF THE BATTERY

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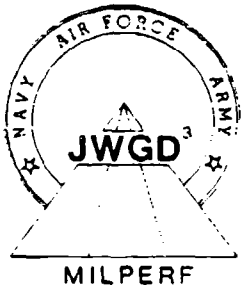

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UNIFIED TRI-SERVICE COGNITIVE PERFORMANCE ASSESSMENT BATTERY (UTC-PAB)

I: Design and Specification of the Battery

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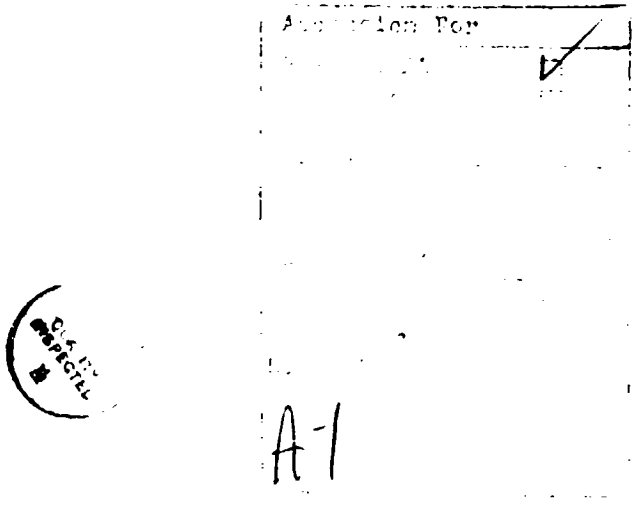
Table of Contents



SUMMARY

The Unified Tri-Service Cognitive Performance Assessment Battery (UTC-PAB) was produced by the Tri-Service Joint Working Group on Drug Dependent Degradation of Military Performance (JWDG3 MILPERF). The UTC-PAB is a standardized instrument for assessment of cognitive performance in a multiple-level drug evaluation program.

The UTC-PAB consists of a computerized test system (Hegge, et al., 1985) and supporting documentation (Perez, et al., 1987). Companion PABs under production by the JWGD3 cover neuropsychological, physiological, psychomotor, physical exercise and the strength, endurance and dexterity tests batteries.

This report represents a historical overview of the UTC-PAB construction, rationale and criteria for task selection and the structural framework by which to organize the 25 tasks. The body of the report provides a brief description, technical specification, data specification, and instructions and training guide for each task. Also included is a listing of primary references.

INTRODUCTION

A. Historical Background of the UTC-PAB Development

The Unified Tri-service Cognitive Performance Assessment Battery (UTC-PAB) is a product of the Tri-Service Joint Working Group on Drug Dependent Degradation of Military Performance (JWGD3 MILPERF). The UTC-PAB represents the primary instrument for a Level II assessment of cognitive performance in a multiple-level drug evaluation program.

The premise for UTC-PAB development is to provide a standardized metric that is responsive to required military-mission abilities and skills and will be a sensitive instrument for detecting performance decrements due to the use of biomedical treatment drugs. The ultimate objective is to develop the capability to answer the question: will drug "x" prohibit successful combat mission accomplishment? The purpose of this report is twofold: the first is to present an historical overview of UTC-PAB construction and relevant theoretical issues; the second is to provide a "users" and software development manual that includes a summary of technical specifications for each of the candidate tests.

The UTC-PAB evolved from a three-day, JWGD3 MILPERF-sponsored Task Area Group (TAG) workshop held in November 1984 at the Naval Medical Research Institute, Bethesda, MD. TAG membership included a representative of the Level I Neuropsychological TAG, two members with backgrounds in performance assessment during sustained operations, and two members specializing in information processing and workload assessment. All members had been involved in the development of performance assessment batteries for specific applications in applied research. The TAG objectives were: 1) to create a formula for UTC-PAB design and standardization, 2) to establish a design for the standardized operating system, and 3) to select tests from existing inventories that met these guidelines. The product was a blueprint for a twenty-five test UTC-PAB menu that would be written in a common software language (i.e., C), and would operate on a standard family of transportable microcomputers (i.e., the IBM PC and compatibles).

B. Rationale and Criteria for Test Selection

Evaluation and selection of candidate tests for inclusion in the UTC-PAB was based on a set of guidelines intended to facilitate battery definition in

a relatively short period of time and to minimize scientific parochialism. These guidelines are listed below:

1. Individual metrics were to contribute to a common menu of standard tests from which investigators could select individual items and tailor a subset (i.e., a mini-PAB).

2. In the event that multiple forms of the same test were proposed, all versions would be included.

3. The "inclusion" rule would also be used to settle disputes over multiple measures purported to assess the same construct.

4. Tests were to be backed by prior research applications. evidence of construct validity, reliability, and sensitivity.

5. To the extent possible, selection decisions were to be based on potential utility rather than the degree to which a metric fit into a single theoretical model.

C. Standardization and the UTC-PAB

Although standardization has been a fundamental rubric for UTC-PAB development, the writers acknowledge that because of the immature status of cognitive science, caution must be observed in any attempt to specify fixed standards for research methodology. However, we regard standardization a necessity for reasonable progress toward a solution of applied human performance problems. As it relates more specifically to our mission, standardization will: (a) provide a mechanism for a concerted state-of-the-art response in a timely and cost-effective manner; and (b) provide a basis for direct comparison and pooling of data collected from independent research efforts. Furthermore, standardization within the given context does not imply scientific stagnation. The UTC-PAB has been designed to be a dynamic system that will undergo several phases of evolution and allow considerable flexibility with regard to experimental design. Built into the system is the option to use and/or augment a "core" subset (derived from the UTC-PAB menu), or construct an entirely unique combination of UTC-PAB elements to meet project-specific requirements.

Finally, by creating a standardized battery and system, we will have assembled a vehicle for establishing a network of "UTC-PAB user" laboratories that will be linked to a central archive for data. This will create a source for building a common data base, provide a mechanism for rapidly establishing

test norms (where appropriate), and allow meaningful comparison of independently derived test results.

A Structural Framework for Classification of UTC-PAB Components

The goal of this section is to provide a structural framework for categorizing tests in the UTC-PAB. This framework is intended to provide preliminary guidelines for selecting subsets of tests from the battery for specific research applications. In addition, the framework may provide a mechanism for developing a predictive model with respect to the effects of individual drugs on performance.

At a general level, tasks in the battery can be classified according to the type of information processing function which is most heavily involved in their performance. Although a variety of such functions are involved in task performance, two dimensions of processing that are particularly critical to assessment of drug effects are: (a) the stage of information processing which is most markedly affected by the demands of the task, and (b) the requirement to divide or selectively employ attentional capacity among sources of information. Several major functions can be distinguished within the stages of processing dimensions. These include perceptual input functions, such as information detection and identification; central processing functions, including a variety of memory and information integration/manipulation functions; and motor output or response execution functions. Integration and manipulation functions within central processing can be further subdivided into those based on linguistic/ symbolic forms of information versus those involving spatial information. The dimensions of processing within this framework are consistent with several current theoretical descriptions of the human information processing system, including those of Wickens (1984) and Shingledecker (1984).

The UTC-PAB incorporates a number of tasks which tap each of the above noted stages of processing and selective/divided attention functions, as outlined below:

I. STAGES OF PROCESSING

A. Perceptual Input, Detection, and Identification

Visual Scanning

Simultaneous Pattern Comparison

Visual Probability Monitoring

Four-Choice Reaction Time Task

Alphanumeric Vigilance Task

B. Central Processing

1. Short & Long Term Memory, Associative Memory

Auditory Sternberg

Visual Sternberg

Continuous Recall

Item Order

Code Substitution

2. Information Integration/Manipulation (Linguistic/Symbolic Mode)

Linguistic Processing

Mathematical Processing

Two Column Addition

Grammatical Reasoning (Traditional)

Grammatical Reasoning (Symbolic)

3. Information Integration/Manipulation (Spatial Mode)

Spatial Processing

Matrix Rotation

Matching to Sample

Manikin Test

Successive Pattern Comparison

Time Wall

C. Output/Response Execution

Interval Production Task

Critical Instability Tracking

II. SELECTIVE/DIVIDED ATTENTION

Dichotic Listening

Stroop Task

Sternberg Memory-Tracking Combination

The framework outlined can be used to guide initial selection of subsets of tasks from the battery for particular applications. For example, one use of the battery may consist of an initial overall screening of the effects of a drug on major information processing functions, followed by a more extensive and diagnostic evaluation for those functions which prove to be degraded

during the initial screening. In most applications, it is desirable that an overall or global screening be conducted with a subset of tasks that are representative of the major processing functions listed above. Such a screen might, for instance, include a subset from the battery which would consist of the visual scanning, Sternberg memory, mathematical processing, successive pattern comparison, and critical instability tracking tasks. This subset is one of several possible options that would represent the various stages of processing functions included in the framework. The Sternberg-tracking combination could also be included in order to assess the effect of the drug on divided attention functions.

Depending upon the pattern of results from the initial global screening, particular functions could be selected for further investigation. For example, if the global evaluation outlined indicated that the Sternberg memory and mathematical processing tasks were principally affected by a particular drug, the memory and symbolic information manipulation/integration functions would represent important candidates for more extensive and diagnostic investigation. This investigation would be accomplished through choice of additional subsets of tasks from the memory and symbolic information manipulation components of the battery.
ation. This investigation would be accomplished through choice of additional subsets of tasks from the memory and symbolic information manipulation components of the battery.

It should be noted that this type of approach involves tradeoffs that should be taken into account. For example, if a specific test chosen to represent a general processing function (e.g., perceptual input) is not affected by a particular drug, this would not necessarily indicate that the processing function under investigation is immune to the effects of the drug. That is, an alternate test representing a different aspect of the same general processing function may have proven sensitive to the effects of that drug. For example, although a short-term memory task selected to represent general memory functions proves insensitive to a drug, it is possible that long-term or associative memory functions might be affected by the drug. Since each task of the battery represents a potentially different processing function within each of the major categories, choice of a limited subset for initial screening and subsequent extensive testing does not provide the comprehensive coverage of the complete battery. Level II screening will,

therefore, need to be guided by the results of previous research (e.g., physiological screening results) as well as by the proposed guidelines.

Any application of the battery to investigate the effects of individual drugs should be designed to permit evaluation of such effects on each task under several levels of difficulty or information processing load.

Such variations in difficulty are recommended because it has been demonstrated that the effects of a variety of stressors and chemical agents (e.g., noise, heat, carbon monoxide) manifest themselves only under high levels of loading or under divided attention or dual-task conditions (Putz, 1979). Use of a single difficulty level in an evaluation, therefore, includes the risk that effects that might have been present at higher levels of loading will not be detected. Of course, the failure to find an effect never guarantees that a drug would not influence performance under conditions that were not tested, but the use of a wide variety of difficulty levels can increase the range of confidence in such a conclusion. The use of several task loading and drug dosage levels also permits an investigator to test for potentially important treatment levels by task difficulty interactions. Loading or difficulty levels can be manipulated by varying the parameters identified with each task in the following sections of this report or by adding a second or concurrent task as in the memory search tracking combination listed above.

Current Status and Related Efforts

At present standardized protocols and technical specifications for the twenty-five UTC-PAB candidate tests have been formally defined. Likewise, the standard operating environment has been designed and software development is underway (Hegge, Reeves, Poole and Thorne, 1985). Many of the participating laboratories were installing the operating system and the rudiments of a laboratory network by mid-1986.

Concurrently, individual manuals for each test are being constructed (Perez, Masline, Ramsey and Urban, 1987). These will include a detailed review of the literature for individual tests, a special reference and summary section for relevant pharmacological studies, and a refined breakdown of test-specific cognitive constructs.

In addition, a service-wide task analysis (Cooper, Schemmer, Fleishman, Yarkin-Levin, Harding and McNelis, 1987) is being conducted that is designed to provide a taxonomic inventory of processes that are critical to combat

performance. Results from this effort will provide a basis for refinement of the UTC-PAB menu, guide future test selection, and define a direct link between performance assessed by the UTC-PAB and military mission effectiveness.

About the Main Body of This Report

The following sections constitute a detailed technical summary of individual UTC-PAB tests. Each test description was written in a standard format using the following major headings:

Task Description

Task Specification

Data Specification

Instructions and Training

The main body has been prefaced with a "quick reference" listing of the UTC-PAB menu and associated constructs. The final section contains a listing of primary references for components of the UTC-PAB.

UNIFIED TRI-SERVICE COGNITIVE PERFORMANCE ASSESSMENT BATTERY (UTC-PAB) MENU

Test Name	Construct
1. Linguistic Processing	Visual, Verbal-Phonetic Coding
a) Physical Letter Match	
b) Category Match	
c) Antonym Match	
2. Grammatical Reasoning (Traditional)	Logical Reasoning
3. Grammatical Reasoning (Symbolic)	Logical Reasoning
a) 1 sentence/2 symbols	
b) 2 sentences (active-positive)/3 symbols	
c) 2 sentences (active-negative or passive-negative)/3 symbols	
4. Two Column Addition	Number Facility
5. Mathematical Processing Task	Number Facility; General Reasoning
a) Single Operator Problems	
b) Two Operator Problems	
c) Three Operator Problems	
6. Continuous Recall Task	Encoding and Storage in Working Memory
a) 1 digit/1 back	
b) 2 digits/2 back	
c) 4 digits/4 back	
7. 4-Choice Serial Reaction Time (Modified Wilkinson and Houghton)	Stimulus Encoding and Categorization; Response Selection and Execution
8. Alpha-Numeric Visual Vigilance Task	Sustained Choice-Reaction Time
9. Memory Search Task (Modified Sternberg)	Stimulus Encoding and Categorization; Response Selection and Execution
a) Visual-Fixed Set (1 "M" set to 100 "p" sets)	
b) Visual-Mixed Set	

(1 "M" set to 10 "p" sets) x 10	
c) Visual-Varied Set	
(1 "M" set to "p" set) x 100	
d) Auditory-Fixed Set	
e) Auditory-Mixed Set	
f) Auditory-Varied Set	
10. Spatial Processing Task	Spatial Rotation; Short Term Memory
11. Matrix Rotation Task	Spatial Rotation; Short Term Memory
12. Manikin Test	Spatial Orientation
13. Pattern Comparison (Simultaneous)	Spatial-Perceptual Speed
14. Pattern Comparision (Successive)	Spatial-Perceptual Memory and Speed
15. Matching to Sample	Spatial Memory; Pattern Recognition
16. Item-Order Test	Short-Term Recall; Recognition
17. Visual Scanning (Neisser's letter search)	Visual Scanning; Perceptual Speed
18. Code Substitution (Wechsler's digit-symbol)	Associative Learning; Perceptual Speed
19. Visual Probability Monitoring	Spatial Scanning; Visual Signal Detection
a) One dial display	
b) Three dial display	
c) Four dial display	
20. Time Wall	Time Estimation
21. Interval Production Task	Response Timing
22. Critical Instability Tracking Task	Manual Response Control
23. Stroop Test	Interference Susceptibility; Response Compatibility
a) Control (Non-interference)	
b) Interference	
c) Combined	
24. Dichotic Listening	Selective Attention
25. Sternberg-Tracking Combination	Dual Task/Timesharing

UNIFIED TRI-SERVICE COGNITIVE PERFORMANCE ASSESSMENT BATTERY (UTC-PAB)
TEST DESCRIPTIONS

1. Title: Linguistic Processing Construct: Visual, Verbal-Phonetic Coding

Task Description: This task is a synthesis of Posner and Mitchell's (1967) letter match task and generic depth of processing tasks (e.g., Shulman, 1974; Craik and Tulving, 1975). It is a standardized loading task that places demands on resources concerned with processing and transformation of linguistic information and requires classification of letter or word pairs. Letter or word pairs are presented on a CRT, and subjects are instructed to respond "same" if the items match on the dimension in question or "different" if otherwise. Three levels of task demand are imposed by the following classification rules: physical letter match, in which letter pairs must be physically identical to match (low demand); category match, requiring that both letters be either consonants or vowels (moderate demand); and antonym match, in which only words opposite in meaning constitute a match (high demand). Each set of trials take three minutes.

Technical Specification: A maximum response time, or "deadline", is imposed in each condition. Stimuli are displayed until the subject responds or until the deadline is reached, thus allowing subjects to pace themselves within the restrictions imposed by the deadline. During training, the deadline is set at 15.0 seconds for all conditions. More restrictive deadlines are used on testing trials. For the physical letter match condition, the testing deadline is 1.0 second; for the category match condition, 1.5 seconds; and for the antonym match condition, 1.5 seconds. Letters are .5 x .7 cm and are viewed from a distance of 62 cm. Positive and negative responses are entered on appropriately labeled keys.

Letter pairs for the physical identity match rule are drawn from the population of all possible (64) combinations of both upper and lower case versions of the letters A, B, C, and E. Positive and negative letter pairs are randomly generated with equal probability. Antonyms were taken from Roget's Thesaurus (e.g., Roget, 1962). To minimize the recognition of repeated antonyms, individual words composing the antonyms are paired with both matching and non-matching words throughout testing.

Data Specification: Unprocessed data are collected and stored on all trials. These data will be a record of: 1) trial start (time 0), 2) problem onset, and 3) subject response, along with the elapsed time of occurrence in milliseconds from the start of the trial.

Standard summary statistics will also be calculated for each trial: 1) number of problems presented, 2) number correct, 3) percent correct, 4) percent response failure errors, 5) percent wrong response errors, 6) percent total errors, 7) mean correct RT, 8) median correct RT, 9) standard deviation RT, and 10) throughput measure.

Instructions and Training: Depending upon the condition being tested, trials begin by giving subjects the appropriate rule to be used in determining whether or not the letter or word pairs constitute a match (physical identity of the stimulus letters, both vowels or both consonants, or opposite meaning of words). Subjects are instructed to respond as quickly and accurately as possible.

Major practice effects are eliminated with 5 to 10 three-minute training trials at each loading level.

2. Title: Grammatical Reasoning Construct: Logical Reasoning (Traditional)

Task Description: This is a direct adaptation of a task developed by Baddeley (1968). It is a linguistic task requiring knowledge of English grammar and syntax and the ability to determine whether various simple sentences and their grammatical transformations correctly describe the relational order of two objects. This implementation differs from the original paper and pencil version in that stimulus items are presented one at a time and are screen centered rather than left-justified to reduce differences in visual search times.

On each trial the letter pair "AB" or "BA" is displayed along with a statement that correctly or incorrectly describes the order of the letters within the pair (e. g. "B FOLLOWS A --- AB", or "A IS NOT PRECEDED BY B --- BA"). The subject decides as quickly as possible whether the statement is true or false and presses the corresponding button on the button box. The task continues for 32 trials or 180 seconds, whichever occurs first.

Technical Specification: The stimulus items differ on five binary dimensions, yielding 32 unique combinations. These dimensions are: 1) Positive or

negative statement, 2) Active or passive voice, 3) Follow or precede verb root, 4) AB or BA letter pair, and 5) A...B or B...A order within the statement. A sixth dimension redundantly determined by the above is whether the statement-pair relationship is true or false.

The eight base sentences (each would have four variations) are listed below:

1.	FOLLOWS	POS	ACT	FOL
2.	PRECEDES	POS	ACT	PRE
3.	IS FOLLOWED BY	POS	PAS	FOL
4.	IS PRECEDED BY	POS	PAS	PRE
5.	DOES NOT FOLLOW	NEG	ACT	FOL
6.	DOES NOT PRECEDE	NEG	ACT	PRE
7.	IS NOT FOLLOWED BY	NEG	PAS	FOL
8.	IS NOT PRECEDED BY	NEG	PAS	PRE

Stimulus items occupy the center five lines of the display. The first line displays the sentence, the second is blank, and the third contains a solid non-blinking cursor to serve as a reference point, prompt, and feedback symbol. The fourth is blank, and the fifth contains the letter pair "A B" or "B A". All lines are centered, all characters are upper case, and display colors are white characters on a light blue background with a dark blue border.

Valid responses are presses of the "True" or "False" buttons. Invalid responses are recorded as "Extras" but have no other effect. Each valid response blanks the cursor and initiates a 500 ms delay and then continues with the next trials. During training trials only, a feedback character is displayed for 500 ms in the center of the screen following a response; the screen is then blank for another 500 ms prior to the next trial. If no valid response occurs for 30 seconds a beep is sounded, the screen is blanked for one second and the next trial is presented.

Data Specification: Each trial records a stimulus code, a response code, and a reaction time value. The stimulus code identifies the item in terms of the six dimensions mentioned above. The response code identifies whether the subject pressed the "True" or "False" button and whether the response was correct, incorrect, or terminated by the deadline. The reaction time value is defined as the time from stimulus presentation to occurrence of the response or is set equal to the deadline value.

The stimulus and response codes may be concatenated or multiplexed into a single variable, and their partial redundancy may be left or removed. The precise method of encoding the data is left to the programmer with the provision that they be recoverable in a standard, reasonably efficient, user-friendly way.

Summary data are: 1) total elapsed time (task duration in seconds); 2) number of trials completed; 3) number and percent correct; 4) number of extras; 5) number of deadline occurrences; and 6) reaction time means and standard deviations for total responses, correct responses, and incorrect responses (not counting deadlines or extras).

Instructions and Training: This task will present you with a series of statements about the relationship between two letters. Each statement will be followed by the letters AB or BA. Your task is to determine whether the statement correctly describes the order of the letters within the pair. If it does, press the button marked "TRUE"; if it does not, press the button marked "FALSE".

Example:		
		A IS FOLLOWED BY B
	Answer = TRUE	AB
		A IS NOT PRECEDED BY B
	Answer = FALSE	BA

Remember to work as quickly and accurately as you can. If you are not sure of the answer, ask for clarification. Many people have difficulty at first with some of the relationships. It is extremely important that you understand all of them before training is complete. Do you have any questions at this time?

3. Title: Grammatical Reasoning (Symbolic) Construct: Logical Reasoning

Task Description: The major differences between symbolic and traditional G.R. is that the symbolic version has three levels of difficulty, and symbols (i.e., *, @, and #) are used instead of the letters A and B.

Stimulus items are sentences of varying syntactic structure accompanied by a set of symbols presented simultaneously. The sentences must be analyzed to determine whether they correctly describe the ordering of the symbols in the symbol set. Task demand is influenced by the amount and complexity of

grammatical analysis. Three levels of grammatical demands are imposed by the following task conditions: 1) single-sentence items of variable syntactic construction that describe the order of pairs of letters (all possible stimuli in the traditional version) -- low demand; 2) items composed of two sentences worded actively and positively, and describing the positions of three symbols -- moderate demand; and 3) two-sentence items worded either actively/negatively or passively/negatively and describing three symbols -- high demand.

Technical Specification: The stimulus population for single-sentence problems is comprised of all possible combinations (32) of the following five binary conditions: 1) active versus passive wording of sentences; 2) positive versus negative wording; 3) keyword "follows" versus "precedes"; 4) order of the two symbols in the sentence; and 5) order of symbols in the symbol set.

For one-sentence (simple) items, the subject's task is to decide whether the symbol set is ordered as the sentence indicates. Examples of one-sentence items are shown below.

1.	@ precedes *	*@ (active/positive; false)
2.	@ does not follow *	@* (active/negative; true)
3.	@ is followed by *	*@ (passive/positive; false)
4.	* is not preceded by @	*@ (passive/negative true)

In the task condition using two sentences (medium and high demand conditions), the object is to determine whether both sentences match in their correctness. If both sentences correctly describes the ordering of the three symbols, or if neither is correct, the subject responds positively. If one sentence is correct but the other not, a negative response is given. Sentences always describe adjacent symbol pairs and are of the same grammatical form (e.g., an active/negative sentence is never paired with a passive/negative sentence). To help equate all conditions, problem sets of 32 (the total number of single sentence problems) were randomly selected for the two sentence conditions with two restrictions. First, when correctly solved, half of the two sentence problems result in a positive response. Second, combinations of sentence answers (e.g., sentence one true, sentence two true; sentence one true, sentence two false, etc.) occur equally often. Equal numbers of active/negative and passive/negative items are used in the high demand condition.

Sample two-sentence items are shown below:

1. @ precedes *
   * follows # @*# (active/positive; nonmatch-false)
2. * follows @
   @ follows # *@# (active/positive; match-true)
3. # does not precede *
   # does not follow @ *#@ (active/negative; match-true)
4. * does not follow #
   # does not precede @ *#@ (active/negative; nonmatch-false)
5. @ is not followed by #
   @ is not preceded by * #@* (active/negative; match-true)

The task is self paced, and deadline limitations for the demand conditions are: LOW--2.5 s; MODERATE--6.5 s; HIGH--7.5 s. Subjects respond by selecting the appropriate key on a two-button key pad. A single trial in any of the three versions consists of 3 minutes of continuous performance.

Data Specification: Unprocessed data and summary statistics are identical to those obtained in the Linguistic Processing Task (i.e., UTC-PAB test #1).

Instructions and Training: In the low demand condition, subjects are instructed to enter a "match" response when the sentence correctly describes the symbol order and a "no match" response when the sentence does not correctly describe the symbol order. In the moderate and high demand conditions, a "match" response is given when both sentences are either true or false. A "no match" response is given when one of the sentences is true and the other is false. Subjects are encouraged to use verbal labels for the task symbols (e.g., "star" for *, "at" for @, and "hash" for #). They are also instructed to respond as quickly and as accurately as possible.

Major practice effects are eliminated with 9 training trials at each of the loading levels. During training, response deadlines of 15 seconds are used.

4. Title: Two-column Addition Construct: Number Facility

Task Description: This is a subject-paced mental arithmetic test (see Ekstrom, French, Harman, and Dermen, 1976) that measures the ability to sum simple addition problems with speed and accuracy. In this test a set of three 2-digit numbers are presented simultaneously in a column format in the

center of the CRT. The subject is required to sum as rapidly as possible and enter the answer, most significant digit first, via a keypad. The column of digits disappear with the first valid key entry and the trial ends when the return key is pressed or when a deadline period of 30 seconds has passed. The task continues for N Trials or T Seconds, whichever comes first.

Technical Description: The three number-pairs are generated pseudo-randomly from the digits 1 through 9; zero is disallowed. The display consists of five lines: The first three lines are the number pairs, vertically aligned. The fourth line consists of four underlined characters. The fifth contains a solid non-blinking cursor located under the left most underlined character. The display colors are white characters on a light blue background with a dark blue border.

Valid response keys are the digits 0 through 9," back-space", and return (enter). Digits are echoed to the screen as entered. Invalid keys (e.g., letters, symbols) are not echoed, but are tallied as "extras".

Back-spacing moves the cursor to the left, up to but not beyond the first digit location, to allow overstrike correction. Each occurrence of back-spacing is tallied as a "correction". The cursor moves to the right with each digit entry unless four digits are already being displayed, in which case it remains in place awaiting a back-space, overstrike, or return.

The return key removes the cursor, initiates a 500 msec delay, and displays a feedback symbol during this delay (e.g., c for correct, e for error; only during training), then blanks the screen for 500 msec and continues to the next trial. If the deadline is exceeded before the return key is pressed, a "beep" is sounded, the screen is blanked for one second and the next trial is initiated.

Data Specification: Each trial generates two "time" values and one response code. The time values correspond to the reaction time of the first valid (digit) response, and the reaction time of the terminating response (return or enter). The response code indicates whether the response was correct, incorrect, or terminated by the deadlines.

If the deadline elapses before the return key is pressed, then the second time value is set equal to the deadline value. If the deadline elapses before a valid key is pressed, then both time values are set equal to the deadline value.

Summary data are listed as follows: 1) total elapsed time (task duration in seconds); 2) number of trials completed; 3) number and percent correct; 4) number of back-space corrections; 5) number of extras; 6) number of deadline occurrences; and 7) reaction-time means and standard deviations for total responses, correct responses, and incorrect responses (not counting deadlines or extras).

Instructions and Training: This test examines your ability to perform arithmetical calculations. The computer will present a column of 3 pairs of digits which you are to add as rapidly as possible. The answer must be given by entering the left-hand digit first (usually the hundreds or tens digit) followed by the remaining digits in order. Be sure you know the entire answer before entering the first digit because the column of digit pairs will disappear from the screen before your entire answer has been entered. If you make a mistake you can use the back-space key to correct it. When you are satisfied with your answer, press the return key.

Example:

29
32
13
??

Answer = 74

Here you would press the 7-key, then the 4-key, and finally the return key. Remember to work as quickly but as accurately as possible. Do you have any questions?

5. Title: Mathematical Processing Construct: Number Facility/ General Reasoning

Task Description: This is a loading task that is designed to test information processing resources that are concerned with arithmetical operations and value comparison of numeric stimuli (Shingledecker, 1984).

This task is self-paced and has three standard versions that require subjects to perform one or more addition and/or subtraction operations on visually presented, single-digit numbers. Subjects respond on a two-button keypad to indicate whether the total is greater or less than a prespecified value of 5.

The three versions, (designed to produce significant differences in reaction-time performance) are: Low Demand--Single Operator Problems (+, -);

Moderate Demand--Two Operator Problems (+ -, - +, - -, only); and High Demand--Three Operator Problems (+ + -, + - -, - + -, only).

Technical Specification: A single trial consists of 3 minutes of continuous performance. Problems are centered on the CRT in a horizontal format (for left-to-right solution) and are followed by an "equal" sign. Reaction times are recorded from onset of stimulus presentation (i.e., a problem) to subject response. Problems are randomly generated with the following restrictions: 1) only digits 1 through 9 are used; 2) correct answers may be any digit from 1 to 9 (except 5); 3) half of the problems presented in a trial will have an answer greater than 5, the other half will have an answer less than 5; 4) when problems are solved from left-to-right, cumulative and intermediate totals must have a positive value; and 5) no problem will contain the same digit twice unless they are both preceded by the same operator (e.g., +6 and -6 would not appear in the same problem).

The task is subject-paced with response deadlines as follows: Low Demand--1.5 s; Moderate Demand--3 s; High Demand--4 s. If a subject responds prior to these deadlines, the reaction time is recorded and the next stimulus is presented. If a subject exceeds the deadline, no reaction time is recorded, the problem is scored as a "response failure", and the next problem is presented. In all cases, the problem is displayed until the subject responds or the deadline is exceeded.

Data Specification: Same as UTC-PAB test #1 (i.e., Linguistic Processing Task).

Instructions and Training: Subjects are instructed to solve the problems by working from left-to-right and to respond as quickly and as accurately as possible. During training, the response deadlines are increased to 15 seconds. Typical training times for the tasks are as follows: Low Demand--7 three-minute trials; Moderate Demand--10 to 14 three-minute trials; and High Demand--10 to 30 three-minute trials.

6. Title: Continuous Recall Task Construct: Encoding and Storage in Working Memory

Task Description: This task (Hunter, 1975) indexes the operator's ability to encode and store information in working memory. It requires serial encoding and recall under a changing memory state.

The memory test consists of a random series of visual presentations of numbers which the operator must encode in a sequential fashion. As each number in the series is presented for encoding, a probe number is presented simultaneously. The operator must compare this probe number to a previously presented item at a prespecified number of positions back in the series. Once the operator has made the appropriate recall, he must decide if that item is the same as, or different from, the probe number. Thus, the task exercises working memory functions by requiring operators to accurately maintain, update, and access a store of information on a continuous basis. Task difficulty is manipulated by varying the number of digits which comprise each item and the length of the series which must be maintained in memory in order to respond to recall probes.

Technical Specification: The task contains three standard loading levels. In the low demand condition, memory items are one digit in length and subjects are required to recall one item back in the series. In the moderate condition, items are two digits long and recall is two positions back. In the high demand condition, items are four digits long and recall is three positions back. In all versions of the task, items are displayed serially on a CRT screen with the following restrictions: 1) test numbers must be randomly generated; 2) only digits 1-9 are used; and 3) roughly half of the probe numbers must result in a recall comparison of "same".

Test numbers and probe numbers are simultaneously presented, as well as terminated. The test numbers always appear below a line centered on the CRT while the probe numbers appear directly above the line.

Test trials consist of 3 min of continuous performance. In all conditions, the task is subject paced within the limits of selected "deadline" reaction times. Maximum acceptable reaction time in the training mode is 15 s for all conditions. If the subject does not respond within 15 s after the onset of a test item, the next item is automatically presented.

In the testing mode, the reaction-time deadlines are reduced: 1.1 s for the one digit, 1 back condition; 1.7 s for two digits, 2 back; and 2.3 s for four digits, 3 back. The number display is approximately 3.17 cm. high, each number is approximately 0.63 cm. x 0.33 cm., and should be viewed from a distance of roughly 60 cm. Responses are entered on a two-button keypad.

Data Specification: Unprocessed data are collected as in UTC-PAB test #1 (i.e., Linguistic Processing Task). Summary statistics are also identical to those described for the Linguistic Processing Task.

Instructions and Training: Subjects are instructed to respond as quickly and accurately as possible to the stimuli. A strategy to suggest to subjects is to first inspect the probe number above the line, and decode whether or not it matches the appropriate item in memory. Next, the number below the line is encoded. Finally, the decision response is made on the keypad.

Major practice effects are eliminated within 5 to 7 three-minute trials at each of three loading levels.

7. Title: 4-Choice Serial Reaction Time Construct: Encoding, Categorization; Response Selection and Execution

Task Description: This test is a derivative of the 4-choice reaction time (RT) task developed by Wilkinson and Houghton (1975). It consists of presentation of a flashing "+" (plus sign) imposed on a cursor in one of four quadrants of a CRT. The task involves pressing "the key" (one of four) on the keyboard that corresponds to the quadrant with a flashing "+". The target stimulus remains in a quadrant until a response key is pressed and then reappears in one of the quadrants. If none of the four buttons is pressed within 2.5 s, a bell rings at 0.1 s intervals until a response is made. Total time for the test is 6 minutes. This test is particularly sensitive to sleep-loss effects.

Technical Specification: The test is initiated by typing 4-Choice. Instructions appear on the screen and indicate that the task will begin after a T is typed on the keyboard. A bell then sounds to indicate that the subject should begin the task. The actual task begins following the first response by the subject.

The screen is divided into quadrants, and a cursor with a flashing "+" sign appears in a randomly selected quadrant. The flashing "+" is reassigned to a quadrant following a response. Target quadrants are selected from the response time of the subject in the following way: last reaction time (last 2 bits) is divided by four; if the remainder is 0, then the

cursor is sent to the upper left quadrant; if the remainder is 1, then the quadrant selected is upper right; if 2, lower left; if three, lower right.

An auditory beep is sounded after 2.5 s of no response and continues until a response occurs. Four keys corresponding to the four quadrants serve as response operanda.

Data Specification: Reaction times of all responses are recorded in milliseconds. Incorrect (i.e., wrong-quadrant) responses are recorded as two's complement and lapses as 2.5 s. Summary statistics include the mean and standard deviations for all correct responses, the 10% fastest and 10% slowest correct responses, the incorrect responses, and counts of number correct and incorrect responses, lapses, and percent-correct responses.

Instructions and Training: Subjects are told that "4-choice" is a test of their reaction time and of their ability to choose the correct response from one of four choices. Instructions to subjects are as follows:

"When you are told to 'start', press the key which corresponds to the position of the blinking "+" on the video monitor. One blinking "+" will be present after the start sequence. Just press one key to start the sequence. Make your choices and responses as quickly and accurately as possible. Continue to do so until the task is over (a bell will sound). Do not talk. Do not take breaks. If your key press rate becomes too slow, a buzzer will sound to remind you to respond more rapidly. To start this task, type 4-Choice, then press return. The task lasts for six minutes."

Training requirements for this task consists of 6 one-minute practice trials.

8. Title: Alpha-Numeric Visual Vigilance Task — Construct: Vigilance (Sustained Choice RT)

Task Decription: This task corresponds to Donder's (1868) disjunctive reaction time (DRT) and has been further developed (Hord, 1982) to measure long-term visual vigilance. The task consists of a CRT presentation of randomly selected alphabetic characters or numbers, at random intervals ranging between 6 and 14 s, with a mean interval of 10 s. The number or character, 10 x 20 mm in size, remains on the screen for 10 ms. Subjects are instructed to press a switch with their thumb everytime an A or 3 appears. Twenty A's and 3's are randomly mixed with 160 other characters and numbers given during this 30 min. task.

Technical Specification: The test is initiated by typing R-Alpha which directs a prompt to appear on the screen. Striking of any follow-up key then begins the actual task within 6 seconds after this latter response. Random intervals for alphabetic character/number presentations range between 6 and 14 seconds, with a mean interval of 10 seconds. The stimuli are 10 x 20 mm in size and remain on the screen for 500 ms. An auditory "beep" signals the end of a test. Stimuli are from a designated list of numbers and letters, and selection is randomized for every run.

Data Specification: Data collected include all responses during a 30 min session, the number of correct responses (button presses following an A or 3), the number of errors of omission, the number of errors of commission, and reaction times (in milliseconds) for individual responses. The means and standard deviations for the correct responses, the five slowest correct responses. and the five fastest correct responses are also recorded, along with the percent correct responses and percent correct detections. An error of omission is declared when responses to an A or a 3 are not made within 5 s. Commission is defined as a response to non-As and non 3s and is scored as two's complement. In computing mean reaction time as well as the five slowest responses, errors of omission are added as reactions times of 5 s.

Instructions and Training: Extensive practice is not required for this task. One or two sets are usually sufficient to familiarize the subject with the characteristics of the task and target stimuli.

Subjects are instructed to monitor the video display and respond whenever they have detected an A or 3. If the character is any letter/number other than an A or 3, no response is required. Subjects are told that randomly selected alpha-numeric characters will appear at random intervals between 6 and 14 seconds. Duration of the task is also indicated.

9. Title: Memory Search Tasks (Modified Sternberg)

Construct: Encoding, Categorization; Response Selection and Execution (visual and auditory modalities/ short term working memory)

Task Description: In general, the task (Sternberg, 1969) requires a subject to maintain in memory a "study set" of alphabetic characters. Subsequent to presentation of a "memory" set (m-set), individual probe letters are presented to the subject for classification as members of the m-set (positive probes) or non-members of the m-set (negative probes). Subjects respond by pressing the appropriate key on a two-button key pad.

Six standard versions of the task are available in the battery. In each version, m-sets of 1, 2, 4, and 6 items are available. In addition, a single trial for any version will entail the presentation of 100 probe letters for classification. The versions differ as follows:

1. Visual Fixed Set (V-FS). Both the m-set and probe letters are presented on a CRT. A trial consists of the presentation of one study set followed by 100 probes for classification with respect to that set.
2. Visual-Mixed Set (V-MS). The stimuli are presented as in V-FS. However, 10 separate m-sets of equivalent size are used in a trial. Each m-set is followed by 10 probes for classification with respect to the set.
3. Visual-Varied Set (V-VS). The stimuli are presented as in V-FS version. However, a trial consists of 100 m-sets of equivalent size, each of which is followed by a single probe item.
4. Auditory-Fixed Set (A-FS). The procedure is equivalent to the V-FS version with the exception that the probes are presented acoustically using a speech synthesis system. M-sets are presented both visually and aurally.
5. Auditory-Mixed Set (A-MS). The procedure is equivalent to the V-MS version with the exception that the m-set and probes are presented acoustically as above.

6. Auditory-Varied Set (A-VS). The procedure is equivalent to the V-VS with the exception that stimuli are presented auditorily.

The chronological series of events for the fixed, mixed, and varied versions are established as follows:

Fixed Set Versions. a) m-set inspection time, terminated by onset of subject's start response, b) first probe onset, one second following onset of subject's start response, c) reaction time onset of probe to onset of subject's choice response, and d) response probe interval fixed at 300 ms (onset of choice response to onset of probe). A trial consists of the presentation of one study set followed by 100 probes.

Mixed Set Versions. a) m-set inspection time, terminated by onset of subject's start response, b) first probe onset, one second following onset of subject's response, c) reaction time onset or probe of choice response, and d) response probe interval fixed at 300 ms following tenth choice response. A trial consists of 10 m-sets, each followed by 10 probes.

Varied Set Versions. a) m-set inspection time fixed and one second, b) probe stimulus onset 300 ms following offset of study set, c) reaction time onset of probe to onset of choice response, and d) new study probe follows each m-set. A trial consists of 100 m-sets each, followed by one probe.

Data Specification: Unprocessed data records will be stored for all test trials. These records will include each occurrence of all events along with an elapsed time since the start of the trial measured in ms as follows: 1) trial start, 2) onset of m-set, 3) offset of m-set, 4) onset of probe item, 5) onset of subject response to probe, and 6) onset of deadline alarms.

In addition, the specific m-sets and all probes used in a trial will be recorded. Standard summary statistics include: 1) mean m-set inspection time, 2) mean correct reaction time to probes, 3) standard deviation reaction time to probes, 4) median reaction time to probes, 5) mean correct RT to positive probes only, 6) standard deviation to positive probes only, 7) median to positive probe only, 8) mean correct RT to negative probes only, 9) standard deviation, 10) median, 11) trial duration, 12) number of response failure errors, 13) percent of response failure errors, 14) number of incorrect response errors, 15) percent incorrect response errors, 16) number of total errors, 17) percent total errors, and 18) throughput errors.

Instructions and Training: In all versions, subjects are told to respond to the probe stimuli as quickly and accurately as possible. However,

accuracy is emphasized, and subjects should attempt to keep error rate below 5% in any trial. Procedural instructions may be derived from the task descriptions. In the fixed and mixed set versions where the inspection period for the study set(s) is determined by the subject, subjects should be told to take only enough time to insure accurate representation of the study set in memory.

Precise training times for the six versions of the tasks described in this document have not been determined. However, extrapolation from similar tests indicates that major practice efforts are eliminated within seven to sixteen trials with each m-set size.

10. Title: Spatial Processing Task — Construct: Spatial Orientation Rotation and Short-Term Memory.

Task Description: The task (Chiles, Alluisi, and Adams, 1968) requires the operator to view a series of histograms presented one at a time. The operator must determine whether the second histogram in each set of two (the "comparison" item) is identical to the first (the "target" item), and respond either positively or negatively on a two-button keypad. Target and comparison histograms are marked with the numbers 1 and 2, respectively, so that subjects can keep track.

Task demands are placed on the operator when two-bar histograms are presented with comparison items in the 0 degree orientation. Four-bar stimulus pairs with comparison items at the 90 degree and 270 degree orientation represent a moderate loading condition. Finally, six bar comparison histograms presented at the 180 degree orientation impose relatively high demand on the operator.

Technical Specification: Computer-generated two, four, and six bar histograms are displayed one at a time on a CRT screen. Bar heights vary from 1 to 6 arbitrary units. No two bars in a histogram are the same height, and any of the six bar heights may appear regardless of the number of bars in the histogram. The first histogram pair is always presented in a vertical orientation with a horizontal line under the figure and the number 1 underneath. Comparison histograms are presented at 0 degree, 90 degree, 180 degree, and 270 degree orientations and are also underlined and accompanied by a "2" to distingish them. Target histograms are randomly selected for all

possible combinations of bar heights given the number of bars in the histogram. Generation of comparison items is also random with the restriction that roughly half of the comparisons are identical to the target. When displayed on a CRT, one unit of bar height is approximately .85 cm. The tallest bar (6 units) is, therefore, about 5.1 cm high. Bars are roughly .5 cm. wide and are separated by .4 cm. spaces. Average viewing distance is 60 cm.

The task is performed in 3-minute trials and targets are displayed for 3 seconds, followed by a 1 second pause. Comparison histograms are displayed for a maximum of 1.5 seconds in the two bar condition, 2.5 seconds in the four bar condition, and 3.5 seconds in the six bar condition. If responses are entered before these deadlines are reached, the screen goes blank for the remainder of the deadline period. Only responses made during the interval between comparison onset and the end of the deadline period are accepted. Positive and negative responses are input on two appropriately labeled keys.

Data Specification: Unprocessed data and summary statistics are as described for the Linguistic Processing Task (UTC-PAB test #1).

Instructions and Training: Subjects are told to respond as quickly and as accurately as possible to the comparison stimulus. All training is conducted with a 15.0 second deadline for response. Stable performance is achieved with 6 to 10 training trials (3 minutes each) at each loading level.

11. Title: Matrix Rotation Task Construct: Spatial Short-Term Memory

Task Description: A series of 5 x 5 cell matrices are presented (one at a time in the center of the CRT), with 5 illuminated cells per matrix. The subject is required to compare successive displays and determine if they are the "same" or "different" from the immediately preceding matrix. Response requires pressing one of two keys designated as "same" or "different".

There are two ways for a matrix to be identical to the preceding matrix. Either exactly the same cells are illuminated but the matrix is rotated 90 degrees to the right, or exactly the same cells are illuminated but the matrix is rotated 90 degrees to the left. Two successive matrices are never presented in exactly the same orientation. Trials are one minute in length with 30 second breaks between trials (see Phillips, 1974; also Damos, 1986).

Technical Specification: There are 100 primary stimuli and a 90 degree right rotation version for each stimulus. The 90 degree left rotation can be easily generated. The "same" response is made by pressing a key under the subject's left index finger. A "different" response is made by pressing a key under the subject's second finger. Response times must be measured from the onset of the stimulus to the response. A keypad is to be operated by the left hand.

The stimulus remains on the screen until the subject makes a response. The matrix measures approximately 8 x 8 cm and is centered horizontally on the screen and slightly above center. The first matrix is displayed at the start of the trial and remains on the screen until the subject makes a "dummy" response (by pressing the same key). The second stimulus is presented immediately after the response and remains on the screen until the subject makes another response, etc. All trials are 1 minute long with 30 second rest pauses between trials.

Data Specification: For each trial, the percent errors and average correct reaction time are obtained for each subject. The mean, standard deviation, and range are obtained on each trial for the percent correct and average correct reaction time. Performance measures obtained after the first 20 min of practice usually can be analyzed using common univariate techniques; the percent correct and average reaction time scores are typically uncorrelated and the variances homogeneous.

Instructions and Training: This task requires 20 min of practice. Instructions to the subject are:

> "The task you are to perform is a memory task. You will perform this task with your left hand. At the start of each trial, you will see a matrix with five illuminated cells. As soon as you have seen the matrix, press the "same" key with your index finger. If you think different cells are illuminated, press the "different" key with your second finger.
>
> As soon as you press a key, a new matrix will be presented. Now you must compare this third matrix to the second matrix. After you have made a response, a fourth matrix will be presented. You must compare this matrix to the third matrix, etc. In other words, you will always compare the displayed matrix with the one immediately preceding it to

determine whether the current matrix is identical to the preceding one or different.

There are two ways for a matrix to be identical to the preceding one. Either exactly the same cells are illuminated, and the matrix is rotated 90 degrees to the left, or exactly the same cells are illuminated, and the matrix is rotated 90 degrees to the right. For example, suppose your first matrix looks like Figure 1. When Figure 1 is rotated 90 degrees to the right, it looks like Figure 2. Be sure to compare the two so you can see the rotation. When Figure 1 is 90 degrees to the left, it looks like Figure 3.

Remember, you must determine if the current matrix is different from the preceding matrix or identical to it but rotated 90 degrees to the left or right. Keep your fingers on the keys at all times during the trial.

Two successive matrices are never presented in exactly the same orientation. Each time you make a response, a new matrix will be presented. All trials will be one minute long with a 30 second break between trials. After ten trials, you should be able to make about one response every second with 95% of them correct. However, it is more important to be accurate than fast.

Press print and return to see the instructions again or just press return to start the test."

12. Title: Manikin Test Construct: Spatial Orientation; Spatial Transformation

Task Description: The Manikin Test described here is a derivative of a task developed by Benson and Gedye (1963). The test is designed to index the ability to mentally manipulate objects and determine orientation of a given stimulus. The manikin is a human figure standing inside either a green circle or a red square (the sample or standard stimulus), holding a green circle in one hand and a red square in the other (the comparison stimuli). The objective for this task is to determine which hand (i.e., right or left) holds the matching object. The subject indicates an answer by pressing one of two keys or buttons with the corresponding right or left index finger. The manikin may appear either upright or upside down and facing either toward or away from the subject. The 16 combinations of orientation, stimuli and

side are pseudo-randomly ordered and presented once each in 16-trial blocks. The number of blocks selected for a given training or test session is under experimenter control.

Technical Specification: The manikin and its surrounding circle are centered in the middle of the display area and occupy approximately the full height available. The proportions, general outline and location of major features are taken from Leonardo da Vinci's "Canon of Proportions." The legs are intermediate to the two positions shown in the original. The arms are lowered so as to project through the end points of the circle's horizontal diameter and axis of rotation which is also coincident with the figure's waist. The diameter of the comparison circle is approximately equal to the shoulder width demarcated in the original. It is located on the horizontal axis of rotation such that the outer circle intersects it at its vertical diameter rather than at its geometric center. The size of the outer square is adjusted to pass through this same point. The comparison square is similarly located after its size is adjusted for perceptual rather than geometric equality. The sample stimuli are discernably thickened (e.g., 8-10 pixels on a 640-pixel screen), and all stimuli are color-filled. The manikin is clothed in such a way as to make the front and back easily discriminable, using details such as hair line, facial features, beard, lapels, shirt pocket, necktie, belt buckle, slash pockets, fly, collar back, belt loops, hip pockets, and buttocks. The figure remains displayed until the subject makes a valid right or left response. As soon as the subject responds, the screen is blanked for one second or until the next stimulus can be generated, whichever is longer. If the subject is pressing a response key when the stimulus is due, a beep is sounded and presentation is delayed for five seconds.

Data Specification: Response latency (measured with one ms accuracy) is recorded for each trial. The timing begins with the presentation of the stimulus and concludes with the subject's response. Individual trial data include the subject's response, the correct answer, the orientation of the figure and the latency in ms. Summary statistics include the number of trials completed, number or percent correct, and the mean, median, range and standard deviation for latencies calculated separately for total, correct, incorrect, left hand and right hand responses.

Instructions and Training: Instructions to the subject differ for the keyboard and button box versions as indicated by parentheses in the following:

"You will see a man inside either a circle or a square, holding a circle in one hand and a square in the other. You must decide as quickly as you can which hand holds the matching object and press either the left or right (key)(button) accordingly. For example, if the man is inside a circle holding a square in his right hand and a circle in his left, you would press the left (key)(button). The man may be upside down or upright and may be facing toward or away from you.

Keyboard Version: (Place your fingers on the bottom row of keys with your left index finger on 'V' and your right index finger on 'M'. Press only one index finger.")

Button Box Version: (Place your left index finger on the Left button and your right index finger on the Right button. Press only with one index finger.")

Training to asymptotic performance requires 36 to 40 16-trial blocks, on the average, with some subjects taking longer. Distributed practice is generally more effective than massed. Reasonable training procedures would give one or two sessions per day, with 4 to 6 blocks per session, for a total of 36 to 40 blocks. During training, but not testing, feedback is given after each response. If the graphics hardware allows the text to be displayed without compromising the generation of the next stimulus, then the word "Correct" or "Incorrect" will be displayed for one second in the center of the screen following each response. If this would increase stimulus generation time beyond the one-second target value, then the screen will remain blank and incorrect responses will be followed by an audible beep.

13. Title: Pattern Comparison (Simultaneous) Construct: Perceptual Speed; Pattern Recognition

Task Description: The Pattern Comparison Test (Klein and Armitage, 1979) is designed to measure perceptual speed, an aspect of spatial ability. The subject views two eight-dot patterns that are displayed adjacent to each other. The pattern on the left side of the screen is designated the target pattern. The task is to determine whether or not the two patterns match and

respond by pressing one of two buttons labeled "same" or "different". There are 60 trials per test with half of the patterns matching.

Technical Specification: Two eight-dot patterns are enclosed inside borders that form a box around each pattern. The X and Y coordinates are randomly selected. The screen is blanked, and pattern one is drawn. A random determination is made to reproduce pattern one or plot a different pattern. Pattern two is then plotted, and both patterns are displayed simultaneously.

A single trial consists of presenting the stimulus and obtaining the response. There are 60 trials per test, 30 trials matching. "Same" or "Different" trial-order is re-determined for each test.

The display consists of two equivalent rectangles with the borders visible and displayed as blue lines. The rectangles are displayed side by side and give the appearance of dividing the screen into a left and right half. The pattern of dots is displayed within the two borders in a random fashion (with the restriction that no dots will be immediately contiguous in any direction). The configuration of the display in the right rectangle differs depending on whether or not it is a matching trial. On the matching trials, the pattern in the right rectangle will be identical to the target pattern in the left rectangle. On "different" trials, one dot in the right pattern is displaced from its position in the target pattern. The displaced dot is displayed at a randomly determined position and is repositioned sufficiently for a perceptible difference to exist between the two patterns (minimum offset of the re-located dot is eight pixels from its original position). An algorithm for ensuring a sufficient displacement may be used for this purpose (Irons and Rose, 1984). The dots are approximately 1 mm in diameter.

The response manipulandum is a box with two buttons labeled "same" and "different". The subject responds by pressing one of the buttons.

Data Specification: Response time (in ms), response accuracy and trial type (i.e., same or different) is recorded for each trail. Summary statistics include: mean and median response latency, range and variance of response latencies, and total number of correct trials. These summary statistics are provided separately for the 30 "same" trials and the 30 "different" trials. In addition, a provision is made to examine the data on a trial-by-trial basis with the response latency, response accuracy, and trial type displayed.

Instructions and Training: Instructions to the subject are: "You will see two patterns of dots on the screen. One pattern will be on the right-hand side of the screen, and the other pattern will be on the left-hand side. You will see both patterns at the same time. Each pattern is made up of 8 dots. Your job is to indicate whether the patterns on the screen are the same or different. Press the button labeled "same" if you think the patterns are the same or press the button labeled "different" if you think the patterns are different. You should try to answer as fast as you can and still be accurate."

Ten training trials are given; five trials will be "same" and five are "different" trials arranged in random sequence. The presentation procedures are the same as those followed in the test. During training, when a subject makes an incorrect response, the screen will blank and the following message appears for 5 seconds, "That was an incorrect answer. The two patterns were X", (X is either "same" or "different" depending on the correct answer for the trial)." Following display of the error message, the same trial is repeated.

14. Title: Pattern Comparison (Successive)

Construct: Perceptual Speed/ Short-Term Spatial Memory

Task Description: This is a test of visual pattern recognition and spatial memory; functions generally held to be subserved primarily by the right cerebral hemisphere (Thorne, Genser, Sing & Hegge, 1985). A random pattern of "dots" is displayed briefly on the screen and then followed, after a blank retention interval, by a second pattern that may be the same or different. The subject decides which as quickly as possible and presses the appropriate button or key. The task continues for N trials (e.g., 20) or T seconds (e.g., 180), whichever comes first.

Technical Specification: The physical appearance of the pattern is particularly important in this task. Both the perceptual appearance and the ease of discriminating different patterns are known to be sensitive to hardware considerations such as monitor size, display area used, character set available, character block size, pixel aspect ratio, and phosphor persistance. For these reasons some parameters of the program have to be determined experimentally and finalized later. The task can be programmed either in text

mode or graph.:s mode. The original but more restrictive text mode is described here.

The screen is considered to be a cellular character array of up to a maximum of 25 rows and columns. Only N of the rows and columns are actually used (tentatively 14). In general, the row and column locations do not correspond to the successive character positions on a standard 24-by-40 or 25-by-80 display. They are determined by the character size and the aspect ratio so that (1) the vertical and horizontal physical separation between adjacent cells are approximately the same, (2) the rectangular outline or envelope is approximately square, and (3) the square occupies "most" of the central display area.

The "dots" are depicted as a white asterisks on a dark blue background. The random pattern generated on each trial corresponds to a "Latin Square", where each row and column contains one and only one dot, and N-1 blanks. This pattern is displayed for X ms (tentatively 1500). The screen is then blanked for Y ms (tentatively 3000). A second pattern is then displayed until the subject responds or a deadline is reached. On one half of the trials, randomly determined, the second pattern is the same as the first. On the other trials, N randomly selected dots (tentatively 3) exchange horizontal positions (columns) while retaining their original vertical (row) locations. Although the order of Same and Different trials is randomized, the number of each is exactly equal not merely equal on the average.

Non-valid button presses increment the "extra" counter but have no other effect. A valid response initiates a 500 ms delay, optionally displays a feedback character at the top center of the screen during this delay, blanks the screen for 500 ms, and then continues to the next trial. Reaction times are timed from the onset of the second pattern. If no response occurs after 30 seconds a "beep" is sounded, the screen is blanked for one second, and the next trial begins.

Data Specification: Each trial generates a reaction time and a coded value indicating whether the second pattern was the same or different and whether the response was correct, incorrect, or timed out. Summary data are: 1) total elapsed time (task Duration), 2) number of trials completed, 3) number and percent correct, 4) number of extras, 5) number of time outs (deadlines), and 6) reactions time means and standard deviations for: a)

total responses, b) correct responses, and c) incorrect responses (not including time outs).

Instructions and Training: "This task is designed to examine your ability to remember spatial relationships. The computer will present a pattern of dots (asterisks) distributed across the screen. Although this pattern will only be present for a very short time, look at it closely and try to remember it during the subsequent retention interval while the screen is blank. Then the computer will present a second "test" pattern which will either be the same as or different from the first pattern. You must decide as quickly as possible which is true and press the "same" button if it is the same or the "different" button if it is different.

As soon as you enter your answer, the computer will begin to present another memory pattern followed by a test pattern, so you will have to pay close attention."

Training requirements are 10 sessions of 20 trials each.

15. Title: Matching to Sample Construct: Spatial Memory; Pattern Recognition

Task Description: Matching-to-sample is a task in which the subject is required to respond correctly to stimuli that correspond in some fashion to a sample stimulus (Skinner, 1950). A single 4 x 4 matrix is initially presented in the center of the screen as a sample stimulus to the subject. The sixteen cells of the sample matrix consist of two colors, red and yellow. For each trial presentation of a matrix, the number of cells that are of one color vary at random from only one cell through 15 cells. While the sample matrix is present, the subject presses a center response button and the sample matrix is removed from the screen. One and a half seconds later two separate 4 x 4 matrices are presented side by side on the screen. One is identical to the sample matrix and the other matrix differs from the sample matrix by one cell. The subject's task is to indicate by pressing the appropriate response button (left or right), which matrix matches the preceding sample matrix. The task consists of 30 trials, 15 where the comparison matrix that matches the sample is presented on the left and 15 where it is presented on the right.

Technical Specifications: The sample stimulus is a 4 x 4 matrix that measures 3.5 cm wide and 3.0 cm high and is presented in the center of the

screen. The sample matrix is filled with sixteen red and yellow cells. The matrix and the cells are outlined by thin, white line borders. The color of the 16 cells for each sample stimulus presentation is determined randomly. The color of the 16 cells can vary from one cell red and 15 cells yellow, to 15 cells red and one yellow. The only requirement is that at least one cell be of the other color. The sample stimulus matrix is displayed at the start of a trial and remains on the screen until the subject makes a response on the center response button. The stimulus matrix is presented in completed form such that the subject does not see the matrix constructed (drawn) on the screen. The screen is cleared after a center response, and following a 1.5 second interval, two comparison stimuli are presented on the screen. One of the stimuli is a 4 x 4 matrix that is identical to the sample matrix and the other stimulus, a 4 x 4 matrix that differs from the sample matrix by one cell. The one cell that is changed in the other stimulus matrix to make it differ from the sample matrix is determined randomly.

The two comparison stimuli are presented side by side with approximately 3.5 cm distance between them. The distance between the two matrices is exactly the space on the screen that was occupied previously by the sample matrix. The comparison matrix that is identical to the sample matrix will appear on the right side of the screen for half of the trials and on the left side for half of the trials as arranged by a random determination. The subject is to push a left response button if the matching matrix is on the left and is to push a right response button if the matching matrix is on the right. Following a left or right response, the screen is cleared for one second, and then the sample stimulus for the next trial is presented.

A single trial consists of presenting the sample stimulus, obtaining a center button response, presenting the two comparison stimuli, and obtaining either a right or left button response. There are 30 trials to the test. On 15 trials the matching comparison matrix will be on the left and on 15 trials it will be on the right. If a center key response does not occur in the presence of the sample matrix for 60 seconds, the two comparison stimuli are automatically presented as if a response had occurred. If either a left or right response does not occur in the presence of the comparison stimuli for 60 seconds, the present trial terminates as if a response had occurred.

Data Specification: Two response latency measurements are recorded for each trial. The first response latency begins with the presentation of the

sample matrix and concludes when that stimulus is cleared from the screen. The second latency measurement begins with the presentation of the two comparison matrices and concludes when they are cleared from the screen. Response latency will be measured in ms. The subject's response to the comparison stimuli (right or left) and the correct answer will be recorded for each trial.

The following summary statistics are required: Percent correct responses, mean and median response latencies, range and variability of response latencies. Provisions are made to examine trial by trial performance. This includes individual response latency, type of response (right or left), and correct response.

Instructions and Training: Instructions to the subject are: "At the start of a trial you will see a single matrix made up of red and yellow cells. This is the sample matrix for that trial. When you press the center button the sample matrix will be removed from the screen and you will then see two comparison matrices on the screen, side by side. One of these two matrices will match exactly the sample matrix that was on the screen and the other matrix will differ slightly. Your task is to determine which of the two comparison matrices is the one that matches the sample matrix.

If you think the matrix on the right matches the sample matrix, press the right button. You should try to decide which matrix matches the sample one as quickly as you can while still being accurate."

The training session consists of 10 trials presented in a manner similar to the main matching test. During the training session, the subject will be provided with feedback and a correction procedure will be in effect. During training, when the subject makes an incorrect response, the screen will clear and the message, "That was an incorrect answer," is displayed for four seconds. Following the message, the same trial sample matrix is presented again. The training session continues until 10 trials have been completed correctly.

16. Title: Item-Order Test Construct: Short-Term Memory; Item Recognition

Task Description: This test is designed to measure short-term memory ability (Wilson, Pollack and Wallick, 1986; Underwood, 1980 (Personal Communication); Jahnke, (In press), by means of a recognition paradigm. A

string of consonants (i.e., the "target" string) is displayed on the CRT for two seconds and then the screen blanked for 2.5 seconds. Immediately following the blank display, a new string of letters (i.e., the "test" string) is presented. The object is to indicate whether the test string is identical to the target string. The subject makes his/her response by pressing one of two buttons labeled "same" or "different". The test string bears one of three possible relationships to the target string: (1) the two strings are identical, (2) the same letters are in the two strings but the letters are in a different order, or (3) the two strings have different letters. Both of the two latter cases qualify as "different".

Technical Specification: The letters in both the target and test strings are 2.5 cm high and are in upper case format and are centered on the CRT. The strings are restricted to consonants. They are randomly selected from the pool of all English consonants. Each string consists of seven letters.

The test is composed so that half of the trials require a "same" response. The "different" trials are half item-different and half order-different. An item-different trial is one where the test string has one new letter in it that replaces a letter that was in the target string. An order-different trial is one where the test string has two items interchanged in the ordinal position as compared to the original order in the target string. In the order-different strings the letters that are interchanged are always contiguous. The letters that are replaced or interchanged are selected randomly for each trial with the restriction that the first and last letters in the target string are never changed in the test string. The occurrence of the "same" and "different" trials in the test is determined randomly.

The presentation of one target string and its corresponding test string constitutes a trial. The test consists of 40 trials (20 "same" and 20 "different").

The target string is presented for two seconds. The screen is blanked for 2.5 seconds before the test string is presented. Following the subject's response to a test string, a row of stars is displayed for 500 ms to signal the start of a new trial.

Data Specification: Response accuracy and response latency for each trial is recorded. The measurement of response latency begins with the

presentation of the test string and concludes when the subject presses a response button. Response latency is measured with an accuracy of one ms. Response accuracy is simply whether the response is correct. The test analysis provides the total number of correct responses made on the test, the number of correct responses made on the "same" trials, the number of correct responses made on the "item-different" trials and the number of correct responses made on the "orderdifferent" trials. The median and mean response latency for the entire test is provided, as well as the median and mean response latency for the "same" trials, "item-different" trials and "order-different" trials.

Instructions and Training: Instructions to the subjects are: "You will see, displayed on the computer screen, a string of seven letters for a short time. Study the letters so that you will remember both what letters were on the screen and the order they were in. The screen will go blank for a short time and then you will see seven more letters. You are to decide whether these six letters are exactly the same as the six letters you just studied. Press the "same" button if they are exactly the same and press the "different" button if they are different. If there is a letter in the test string that wasn't in the string you studied, you would press "different". If the letters are in a different order than they were when you studied them, you should press "different". Press the button as soon as you decide whether it is the same or different; speed is important but try to be as accurate as possible. After you press the button, you will see some stars briefly on the screen. These stars mean that you should prepare to study a new string of letters."

Training for this test is as follows: Ten practice trials are given to the subject following the same procedures used in the test proper. When a subject makes an incorrect response to one of the training trials, the message "That was incorrect." will appear. The target string and the test string is displayed directly below the message. This feedback screen is presented for 5 seconds and then the practice trials continue.

17. Title: Visual Scanning Construct: Perceptual Speed

Task Description: This is a visual search and recognition task representative of many tasks where a subject must scan an area or array of distractor objects in search of one or more target objects. In this

instance, adapted from Neisser (1963), the target and distractor objects are letters of the alphabet arranged as R rows (e.g , 25) of C columns (e.g., 5). The subject scans the array in normal reading order (left-to-right, top-to-bottom) and presses a button as soon as the target letter (e.g. "K") is detected.

In the prototypical procedure used by Neisser, accuracy was checked by having the subject read aloud the line containing the target letter. Since the present implementation does not provide a listener nor voice recognition hardware, two alternative procedures will be described. The first of these uses a button box and a light pen. This is the preferred method but assumes that a light pen is available and that it will work over the necessary distance from the video adapter to the subject's monitor. The second method uses the keypad or keyboard.

Task Specification: (Light pen version)

Each trial begins with a 500 ms presentation of a visual fixation point (character). It is displayed on the top line of the screen three character positions to the left of center (one position to the left of where the array will appear). The purpose of the fixation character is to reduce variability in the subsequent visual search time and to provide a preparatory time cue for the next stimulus presentation. The fixation character may be a right-arrow, a dash, or an asterisk (roughly in that order of preference) depending upon character set availability and appearance.

The stimulus array is generated during the intertrial interval while the display is either blanked, displaying a feedback character, or displaying a fixation character. The array consists of 25 rows and 5 columns randomly generated from the 25 letters "A" through "Z" excluding "K". One randomly selected character within the array is then replaced by the target letter "K", with the restriction that it may not occur within the first three rows or the last visible row.

When the fixation/preparatory interval has elapsed, the array is displayed and the timer is started The array must not scroll, sweep, or be painted on the screen at a discernable rate but must appear within one frame interval triggered from the vertical sync. pulse or equivalent. This implies that it will reside in a different screen page than the fixation character, and that if only one text page is available, the fixation character may have

to be generated graphically. All letters are upper case, in white on a dark blue background.

The subject scans the stimulus array, presses a button on the button box the instant the target letter is recognized, and then has t seconds to touch the target letter with a light pen. (Although the light pen response might appear to be sufficient in and of itself in this application, it contains inherent variability due to different physical movement times, different video beam scan times, and usually to details of the "hit detection" circuitry or algorithm used.)

Detection of a light pen "hit" initiates a 500 ms delay interval, optionally displays a feedback character during this interval (in the same location used for the fixation character), then blanks the array for 500 ms while displaying the next fixation character. If a light pen response is not detected within t seconds (tentatively 3) following the button response, or if no button response occurs for (tentatively) 10 seconds following the array presentation, then a beep is sounded, the screen is blanked for 500 ms, and the next fixation period begins. The task continues for n x 21 trials (e. g. 42) or t seconds (e.g., 300), whichever occurs first.

Task Specification: (Keyboard or Keypad Version)

The fixation stimulus and array presentation are the same as above. However, the occurrence of the button/keypress causes the array rows to be immediately labeled with the numbers 01 through 25. These numbers are displayed to the right of the letter array after one intervening space.

The button is replaced by a designated key on the keypad or keyboard. As with the button response, the subject has (tentatively) 10 seconds to respond. After the response is made and the rows are numbered, the subject has t seconds (tentatively 4) to enter the two-digit target row number. A return or enter is not required and backspace correction is not allowed. In all other respects the second digit entered serves the same functions as did the light pen responses in the above.

Data Specification: Each trial generates a stimulus code, a response code, and two time values. The stimulus code identifies the row and column of the target letter. The response code identifies whether the response was a correct light pen response, an incorrect light pen response, a late light pen response, or a late button response. The two time values are normally the elapsed time from stimulus presentation to the button response and to the

light pen response. These time values are replaced with the appropriate "deadline" values in the case of late (missing) responses. Summary data requirements are: 1) task duration in seconds, 2) number of trials completed, 3) number and percent correct ("late trials" count as errors), 4) number of late button responses, 5) number of late light pen responses, and 6) least-square linear fit, (derived from correct-trial button reaction times and target row locations including: a) slope of regression line (scan time per row), b) intercept (response time for "zero" rows), and c) squared correlation coefficient (r).

Raw and summary data for keypad/keyboard version is analogous to the above if the word "button" is replaced by "detection key" and "light pen" by "second digit".

Instruction and Training: (Both Versions)

"You will be presented with lists of random letters which you are to scan in normal reading order (left to right, top to bottom) in search of the target letter "K".

One-half second before each list is presented you will see an asterisk near the top of the screen. This serves as a warning signal to help you get ready and as a pointer to where the list will begin. You should fix your gaze on the asterisk and prepare yourself for the next list.

When the list appears, try to find the letter "K" as quickly as you can. The instant you locate the "K", press the..."

(Light-pen Version):

"...bottom button on the button box as quickly as you can. You will then have a short time in which to "touch" the letter "K" with the tip of the light pen. When you do so, the letters will disappear and another list will appear a few moments later.

Hold the light pen in your preferred hand (e.g., right if you are right-handed) and position the middle finger of the same hand above the bottom button on the button box."

(Key-pad Version):

"...zero key on the key-pad as quickly as you can. You will then have a short time in which to indicate the number of the row containing "K" by entering it on the key pad. As soon as the second digit is entered, the letters will disappear and another list will appear a few moments later."

Training requirements are 10 sessions of 21 trials each (one trial at each allowable row location).

18. Title: Code Substitution Construct: Perceptual Speed/ Associative Learning Ability

Task Description: The Code Substitution Test is derived from a paper and pencil version of the test contained in the Wechsler Adult Intelligence Scale (Wechsler, 1958) and is designed to index associative learning ability and perceptual speed. A string of 9 letters and 9 digits are displayed across the screen and arranged so that the digit string is immediately below the letter string. There is one digit corresponding to each letter. A "test" letter is presented at the bottom of the screen, below the coding strings, and the subject is to indicate which digit corresponds to that test letter in the display study strings. The letter and digit associates remain the same for the entire test.

Technical Specification: The coding string remains displayed on the screen for the duration of the test. Each test display uses 9 letters randomly selected from the alphabet; digits 1-9 are used for the bottom string. Letters and digits are randomly paired for each test and order is randomly assigned in the coding string.

A single trial consists of presenting the probe stimulus and obtaining the subject's response. There are 30 trials to the test. There will be an inter-stimulus interval of 500 ms between the subject's response and presentation of the next probe stimulus.

The coding string is centered on the screen. The letters and digits are 2.0 cm tall and the letters capitalized. The letter string is displayed 1.25 cm above the digit string and digits are located directly below the corresponding letters. The probe stimulus is designed to match the graphic features of the corresponding letter in the coding string. The probe stimulus is horizontally centered, 6 cm below the bottom of the coding string. The probe stimulus remains on the screen until the subject makes his response.

There will be an interval of 0.25 s between presentations of the probe stimuli. If the subject presses the response button during the interstimulus interval, the screen will blank (i.e., the coding string will be removed) and

the message " Do not press the response button before the test letter appears " is displayed for 5 s. The coding string will then be redisplayed and the test will proceed normally.

The response manipulandum will be a numeric keypad separate from the keyboard. The subject responds by pressing the selected digit on the keypad; it is not necessary to use an "enter" or "return" key to enter the selected response.

Data Specification: The response time (recorded with less than 1 ms error for each trial), and the actual correct answer is recorded for each trial. Summary statistics are: 1) mean and median response times over the 30 trials, 2) range and variance of the response times, and 3) the total number of correct responses. In addition, an option is available that allows examination of test performance on a trial by trial basis for each subject with each response latency, correct response, and subject's response displayed.

Instructions and Training: Instructions to the subjects are: "You will see a row of numbers displayed across the screen. The number row will be below the letter row. The rows will be arranged so that the number directly below a letter is called the "code" for that letter. Your job will be to learn the codes for each letter. You will see, on the very bottom of the screen, a series of tests letters, one at a time. The test letters will all be from the letter row. Your job is to enter the digit on the keyboard that is the "code" for that letter. For example, if the letter "J" was right above the digit "7", then "7" is the code for J. When the letter "J" appears at the bottom of the screen, press "7" on the keypad. Try to answer as soon after the test letter appears as you can, but be sure to be accurate too."

Training involves presentation of a coding string followed by 10 training trials. The general presentation of the training trials follow that of the main test trials, with the exception of providing subjects feedback during the training trials. When a subject makes an incorrect entry during the training trials, the following message is displayed: "That was an incorrect response; the correct response was X" (X will be the actual correct response). This message is displayed across the bottom of the screen for 5 seconds. Then the same probe stimulus is presented again. This procedure continues until all 10 training trials are correctly finished.

19. Title: Visual Probabilty Monitoring — Construct: Spatial Scanning; Signal Detection

Task Description: The visual Probability Monitoring Task, based on a paradigm developed by Chiles, Alluisi, and Adams (1968) is a standardized loading task designed to place demands on perceptual resources devoted to scanning and detection of visual signals. This task includes three fixed loading levels produced by variations in the number of signal sources (dials) and in the discriminability of signals. Subjects are required to monitor one, three, or four computer generated displays having the appearance of electromechanical dials. Each display consists of a row of six vertical hashmarks with a seventh mark offset above the others to indicate the center of the dial. A number appears to the left of each dial to identify it and each dial is circumscribed by a rectangular "bezel". Under normal (non-signal) conditions, a pointer located below the hashmarks moves from one position to another in random fashion to simulate the pointer fluctuations on an actual dial. At unpredictable intervals, the pointer on the display begins to move nonrandomly, staying predominantly to the left or right of the dial. These biases in pointer movement are the targets or "signals" to which subjects are instructed to respond. By pressing an appropriate response key, biased dials can be corrected to the non-signal (random pointer movement) state.

Technical Specification: A single trial consists of 3 minutes of continuous monitoring. Test trials are equally likely to contain 2 or 3 signals. Signals may occur at any time within a trial with the restriction that a minimum of 25 seconds separates the offset of a signal and the onset of the next signal. In conditions where 3 or 4 dials are monitored, the dial on which any signal will be displayed is randomly selected.

When no signal is present, the pointer moves to each position with equal probability (1/6). When more than one dial is to be monitored, the pointer movement on each dial is independent of the others. Pointer position is updated at the rate of 2 moves/sec. Dials always appear in the same screen location (i. e., dial #1 is always located at the upper center of the screen, dial #2 at the middle-left, etc.). In the single dial condition, dial #1 is displayed; in the three dial condition, dials 1, 2, and 3 are shown; in the four dial condition, all four dials are displayed.

If undetected, a signal lasts 30 seconds and occurs across 60 pointer moves. When a signal occurs in the high discriminability condition, 57 of the 60 pointer moves appear on one side of the dial (95/56 percent probability bias); in the moderate discriminability condition, 51 of the 60 moves appear on the favored half (85/5 percent probability bias); and in the low discriminability condition, 45 of the 60 moves occur in the bias direction (75/25 percent probability bias). Within these constraints, however, pointer movement is randomly determined. Biases are equally likely to appear on either half of the displays and on any given display. Three significantly different task demand levels are produced by the following task conditions; low demand--one dial at the 95/5 percent bias level; medium demand--three dials at the 85/15 percent bias; high demand--four dials at the (75/25) percent bias level.

Data Specification: Unprocessed data are collected as in the Linguistic Processing Task (i.e., UTC-PAB test #1) with the following events included in the record: 1) trial start (time 0, 2) signal (dial and bias direction) onset, 3) signal offset, and 4) subject response. Standard summary statistics are: 1) number of signals presented, 2) number of correct detections, 3) RT for each correct detection, 4) number of missed signals, and 5) numbers of false alarms.

Instructions and Training: Subjects are instructed to respond only when they are certain that a signal has appeared on a dial. Thus, they are given a strategy which encourages a minimum number of false alarms. Subjects are told that the trial will contain 2 or 3 signals and to respond on a 4 button pad.

Extensive training on the task is not necessary. However, subjects should be given 2 or 3 cued trials at each loading level in order to insure that they are able to discriminate the signal conditions.

20. Title: Time Wall Construct: Time Estimation

Task Description: This is a nonverbal time estimation task (Seppala and Visakorpi, 1983) in which a small object moving at constant velocity passes behind an opaque barrier. The task is to estimate the moment when the object will reappear. It differs from a number of other time-estimate tasks in that discrete mediating responses such as counting or taping are of no direct obvious aid. In this implementation, movement is vertical rather than

horizontal for purposes of visual field symmetry. The barrier contains a hole or notch that is the same shape and size as the object, and the subject estimates the moment when the entire notch will be filled. This implementation uses a nominal ten second time interval.

Technical Specification: The barrier (wall) occupies the lower third of the display area. The notch (i.e., missing block) is centered along the wall's bottom edge. The moving object (falling brick) emerges from the top of the display area and descends at a constant velocity such that its leading edge would reach the botton line of the display at a precisely known time (normally 10 s). The brick appears to pass behind (or into) the wall, after which the timer continues to run but nothing else occurs until the subject responds or a deadline elapses.

The brick and notch are identical small squares whose size dimensions are 0.5 cm square Colors are dark blue border, light blue sky, (upper 2/3rds of display), a light blue notch, and a "brick" pink wall.

The subject estimates the brick's transit time and presses a designated response key. Feedback that an acceptable response has been made is provided by instantly filling the notch with the wall color. After 500 ms the notch reverts to light blue and a new brick begins to emerge from the top of the screen. If a button is pressed before the brick has passed completely beyond the upper edge of the wall, the trial continues without visible change but an "extra" response is counted. If no acceptable response occurs for 30 seconds, then a beep is sounded and the next trial begins one second later. The task continues for ten trials or 300 seconds, whichever occurs first.

Note: In earlier implementation of this task, it was found necessary to write a self-calibration routine into the program using the same hardware timer as used for reaction times. This was necessary to determine delay values for drawing and moving the brick and for determining brick size (size interacts with execution time and perceived smoothness of motion). Calibration involved moving the brick to the bottom of the display rather than just past the wall edge, and then recording the actual elapsed time. Calibration was also found to be necessary to correct for differences between machines and for long term drift in the same machine.

A third reason for calibration, largely due to the use of an Interpreter and possibly inapplicable here, was that execution time varied measurably with the number and size of the other programs and arrays resident in memory

(e.g., the number of task included in the battery). If similar timing variations appear here, then it will be necessary for the program to calibrate itself once on each machine each time a battery is configured or before each run.

Data Specification: Each trial generates at least one time value and a response-code indication whether the response was acceptable, an "extra", or was timed out by the deadline. Times are measured from the start of each trial and will usually have values around 10 seconds. Recorded values for deadline occurrences are set equal to the deadline value itself (e.g., 30 seconds). These times may be recorded as their absolute values for a signed difference from the calibrated (nominally 10 second) standard. Summary statistics are: 1) calibrated standard time value (not necessarily 10 s), 2) total elapsed time (task duration in seconds), 3) number of trials completed, 4) number of "extras", 5) number of time outs (deadlines), 6) constant error (mean estimate minus calibrated standard), 7) proportional error (mean estimate as percent of standard), 8) variable error (standard deviation of the estimates) (msec), and 9) coefficient of variation (100 x std. dev./mean estimate).

Instructions and Training: "In this task, a small pink square will appear at the top of the screen and will move at a constant velocity toward a shielding barrier. When it reaches the barrier you will no longer be able to see it. Your job is to estimate how long it will take the square to reach the small dark notch at the other side of the barrier. Indicate when you think the square has reached the notch by pressing the response button. When you do so, the dark notch will turn pink for a moment and then the next trial will begin."

Training consists of 10 sessions with 10 trials each session.

21. Title: Interval Production Task Construct: Response Timing

Task Description: The task (Michon, 1966) requires subjects to generate a series of time intervals by tapping a finger key at a rate of one to three responses per second. The goal of the task is to maintain equal time intervals by tapping at as regular a rate as possible. The task is run in 3-minute trials.

Technical Specification: A paddle shaped key (approximately 1-1/2 x 3") which operates a microswitch is used to perform the tapping response. The

subject taps with the forefinger of the preferred hand. Intervals are timed from the onset of one response to the onset of the next response. Keybounce phenomena may be avoided in hardware or software design. In addition, intervals of less than 10 ms should be rejected as spurious input.

Data Specification: Unprocessed data for the task is a record of the duration in milliseconds of each successive tap. Summary statistics include two measures of tapping performance: the standard deviation of interval durations and the Interval Product Task (IPT) variability score. Michon (1966) suggested the IPT variability score because it corrects for the partial dependence of error magnitude on interval duration. IPT variability is calculated by the following formula, where N is the total number of intervals produced, T is the total time over which data are collected, and

$$\frac{N}{T}\sum_{i=1}^{N}\left(t_i\right)$$

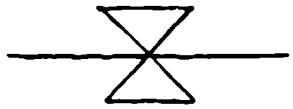
t_i is the difference between successive intervals. A lower IPT variability score indicates more temporally regular tapping and better performance. Typical variability scores range from 10 to 40.

Instructions and Training: Fifteen minutes of practice tapping are adequate for training. Subjects should be instructed to tap at a "personal rate" between one and three times per second, and to become as automatic as possible. Initially, six 30-second practice trials should be run to allow the subject to establish and maintain a tapping rate. The experimenter may need to coach the subject during these trials. It is best if a 2 taps/second rate is established early in training so that the subsequent drift in tapping rate does not lead to unacceptable data. Four 3-minute trials should then be completed to provide sufficient practice, for a total of 15 minutes of training.

22. Title: Critical Instability Tracking Task — Construct: Manual-Response Control

Task Description: This is a loading task (Jex, McDonnell, and Phatak, 1966) that is designed to place variable demands on human information processing resources dedicated to the execution of rapid and accurate manual

responses. In this task, subjects view a fixed target area displayed on a video screen as depicted below:



The cursor (an inverted triangle) moves horizontally (i.e., left and right) from the center of the screen. The task is to keep the cursor centered over the target (a stationary triangle) by manipulating a joystick. The operator's input introduces error which is magnified by the system with the result that it becomes increasingly necessary to respond to the velocity of the cursor movement as well as cursor position. The instability of the system is activated by the subject's movement of the joystick along with an initial error whose value is predetermined. When the subject attempts to maintain the centered position, the error (i.e., degrees off center) of the cursor, is recorded, transformed, and then added back into the system to increase the movement of the cursor. If a boundary is hit, the cursor automatically resets to the center position and after a predetermined amount of time, the task resumes. Based on measures of tracking performance (i.e., average absolute tracking error and number of control losses) and subjective task difficulty ratings, three demand levels have been selected that produce reliably different demand levels. These are determined by lambda values of 1.0, 3.0, and 5.0 for low, medium, and high demand, respectively. The task duration is defined in terms of combinations of three minute trials.

Technical Specification: The forcing function of the task is based upon the following formula:

$$X(new) = [\,[\,X(i) + joystick] * lambda] + X(i-1)$$

where X(new) is the "new" position of the cursor, X(i) is the current position of the cursor, "joystick" is the current value from the subject's joystick, X(i-1) is the last position of the cursor, and "lambda" is the forcing function-multiplier determined by the experimenter. The lambda values may be fixed ranges of 1.0 (low demand), 3.0 (medium demand), and 5.0 (high demand), or they may be varied between the 1.0 to 5.0 range. The fixed lambda value will remain the same throughout the tracking task, maintaining the same demand level on a subject. The varied lambda ramps from a low value to a high value and can be used to increase task demand on a subject as the task proceeds.

The tracking task requires high resolution graphics display (640 x 400 pixel color monitor). The active area of the display is a horizontal, 17 centimeter line of 500 pixels, 250 to each side of the center position. The subject's cursor position is sampled and saved at a rate predetermined by the experimenter. This is accomplished through the use of an interrupt driven interval timer that is plus or minus five percent accurate for the total task time. Upon task completion, the cursor position data are stored on diskette and may be viewed as raw data or summary statistics.

No external forcing function acts upon the cursor position, only the movement of the joystick by the subject and an amount of error due to noise and drift in the joystick.

Data Specification: Unprocessed data records will include average error scores for each consecutive one second interval of a three minute trial. In addition, raw data will include cumulative testing time beginning at the onset of data collection and continuing in increments defined by the data collection rate. At each of the data increments, the offset value (from center) is given. Summary statistics include the following: the final lambda value when the task ended, the Root Mean Square (RMS) offset from center, the task duration, the number of offset samples used in the statistics, and the total number of boundary hits that occurred.

Instructions and Training: The subject is instructed to maintain the cursor in the center position and to avoid hitting the boundaries.

Subjects are given 10 seconds to gain control of the cursor before the trial begins for data collection. Major training effects are eliminated within 6 to 10 trials at each loading level.

23. Title: Stroop Test

Construct: Susceptibility to Response Competition Interference

Task Description: This test is a modified version of the classic paradigm developed by Stroop (1935) and more recently described by Flowers and Stoup (1977). There are three different test versions that can be used. All of the test versions use the words "red", "blue", and "green", and also use red, blue, and green display colors. A single trial consists of presenting a word in a particular display color and obtaining the subject's response. The subject is instructed to respond by pressing a button that

indicates the display color. The actual word presented is irrelevant. A test is comprised of a number of these trials.

In the Control Condition (Version 1), individual words are displayed on video screen with the word and the display color being congruent. The subject is required to press the button on the response box that is the same color as the display color.

In the Interference Condition (Version 2), the words and display colors are randomly paired so that the word and display color are usually, but not always, incongruous. The subject is required to press the button on the response box that is the same color as the display color. The Control test and Interference test are intended to be used together to provide an estimate of susceptibility to response interference. The Control test, if used alone, can serve as a choice reaction-time test.

The Combined Condition (Version 3), is designed to require only one test to measure response interference. A word is displayed on the screen in a particular color and the subject is required to press the button corresponding to the display color. The display color is with red, blue, or green. The test word is either an interference word or a neutral word. The interference words are "red", "blue", or "green" and the neutral words are "gun", "door", and "house". If the test word for a particular trial is an interference word, the display color and the word are incongruous. The display color and the neutral words are paired randomly.

The subject's susceptibility to response interference is indicated by performance differences between the combined control and combined interference trials. Under normal conditions, one expects that performance on the control items will be superior to performance on the interference items.

This difference is most likely due to the fact that the subject is unable to suppress the automatic response of reading each word as it is presented. When the subject reads a word that is incongruent with the presentation color of the item, response competition occurs. This response competition will usually result in slower response latencies and less accurate responses.

Technical Specification:

A. General Information:

1. A stimulus word is defined as having two parts. The two parts are the actual word and the display color. For the Control Condition there are three possible stimuli: the word "red" displayed in red, the word "blue" displayed in blue, and the word "green" displayed in green. For the Interference Condition there are nine different stimuli: "red" displayed in red, blue, or green; "blue" displayed in red, blue, or green; and "green" displayed in red, blue, or green. In the Combined Condition there are 15 different stimuli: "red" displayed in blue or green; "blue" displayed in red and green; "green" displayed in red or blue; "gun" displayed in red, blue, or green; "door" displayed in red, blue, or green; and "house" displayed in red, blue, or green.

2. A response consists of depressing one of three response key that are colored red, blue, and green.

3. The stimuli are determined by randomly pairing a word and a display color for each trial, with the restriction that the word and the display color cannot be the same except in the Control Condition when the word and color must be the same.

4. Response latency refers to the period of time immediately following presentation of the stimulus up to the subject's response (i.e., pressing the response button).

B. Specific Information:

1. A single trial consists of the presentation of a stimulus and the subject's response to the stimulus. There are 45 trials in the complete test for both Control and Interference Conditions. There are 72 trials in the Combined Condition.

2. For both the Control and Interference Conditions (versions 1 and 2), the stimuli are presented in a random order across the 45 trials. In the control condition, there are three possible stimuli and each stimulus is presented 15 times in the test. In the Interference Condition, there are nine different stimuli. Each of the nine stimuli appears five times in the test. In the Combined Condition (version 3), there are a total of 72 trials. There are six different incongruent stimuli and nine different neutral stimuli. Each incongruent stimulus appears six times and each incongruent

stimulus appears four times in the test. Consequently, there are 36 trials with incongruent stimuli and 36 trials with neutral stimuli.

3. For all conditions, the stimulus remains on the screen until the subject makes his/her response. Immediately following the subject's response, the screen will blank and remain blank until the next trial. A brief interstimulus interval (ISI) follows the conclusion of one trial and the beginning of another trial.

The length of this ISI is randomly determined and will fall within the limits of 1-3 seconds. If the subject presses a response button during the ISI, the message "do not press the response button until the word appears" will be displayed for 5 seconds. The stimulus is presented on the screen such that it is centered both horizontally and vertically. The letters in the stimulus words are capitalized and are 2.5 cm tall. The response manipulandum is a box, separate from the keyboard, that has three buttons arranged in a horizontal row. One button will be colored red, one button will be colored blue, and the remaining button will be colored green. The buttons will be approximately 2.5 cm in diameter and require 3-7 oz pressure to depress.

Data Specification: For each trial, the response time is recorded along with the button pressed by the subject, the actual display color, and whether the trial was a control word or an interference word.

The following statistics are also provided: mean and median response time over the 30 trials using the control words, range and variance of response times over the 30 control trials, and the total correct responses over 30 control trials. These same data are provided separately for the 30 interference trials. In addition, an option is available that allows examinination of the individual trial data when desired.

Instructions and Training: The instructions to the subjects are: "You will see a series of words displayed on the screen, one at a time. Each word will be displayed in either red, blue, or green color. Your job will be to determine the color the word is displayed in and to press the button on your response box that is the same as the display color. No matter what the word on the screen is, your job is to press the button on your response box that is the same color as the display color. For example, if the word "red" appeared on the screen displayed in the blue color, you would press the blue button. You should try to work as fast as possible without making any

mistakes. Remember, you should press the button that is the same color as the display color, regardless of what work is actually displayed."

Training requirements are as follows: A set of 12 trials is presented to each subject. These training trials are in a format similar to the actual test trials. If, on these trials, the subject presses the wrong response button, the message "Press the button corresponding to the display color" appears for five seconds. This procedure is repeated until the subject responds correctly on all 12 trials.

24. Title: Dichotic Listening Task Construct: Auditory-Selective Attention

Task Description: The Dichotic Listening Task (Gopher & Kahneman, 1971; Griffin & Mosko, 1982; 1985) requires subjects to attend to auditory information (a specific set of letters and digits) presented to one ear while ignoring similar information presented to the opposite ear, and then, after considering an auditory cue, to switch attention rapidly to the previously unattended ear or maintain attention to the previously attended-ear channel.

Individuals must attend to auditorily presented information and respond to the numbers presented on the command-ear channel using a keypad. The numbers are touched on the keypad in the order of their occurrence on the command ear. Command ear is defined as the left or right ear as specified during the task. The auditory stimulus is produced by a computer controlled speech synthesizer over dual channel headphones.

Technical Specification: Parameters for a 36 trial, Dichotic Listening Task are as follows: Two speech synthesis devices are used, one for each auditory channel. They are computer controlled and auditory stimuli are presented via dual channel headphones at 75 db/Leq(re.: 20 Pa). Individual auditory stimulus duration is 0.7 seconds. One trial requires 18 seconds and a thirty-six trial DLT task with six practice sessions takes approximately 20 minutes. Each DLT trial was divided into two parts. Part 1 consisted of a mix of letters and digits delivered to each ear. Digits are never presented simultaneously to the two ears and no digit is repeated in either sequence. However, simultaneous presentations are presented that consist of identical or dissimilar letters, or a letter to one ear and a digit to the opposite ear. Part 2 of each trial is preceded by a "right" or "left" vocal channel

attend command. The digit and test materials are presented at the rate of one letter or digit per 0.7 second. An example DLT trial is depicted below:

PART 1

Left Ear R 8 N S M Y 2 G B 7 F L 6 R L 5

"Right" (Vocal Channel "attend" Command)

Right Ear Y L 3 S R 4 F Z 9 X F O F N 1 L

PART 2

Left Ear B F 4 3 7 9

"Left" (Vocal Channel "attend" Command)

Right Ear G L 1 5 6 2

Data Specification: Raw data collection: (1) Number correct part 1, number correct part 2, total number correct (3 measures) without regard to number presentation sequence; (2) as above, but numbers are correct only in the sequence of their auditory presentation.

Standard summary statistics: means, standard deviation, minimum, maximum, and standard error, for each of six measures of raw data. Recommendations for common analysis: Repeated measures, analysis of variance.

Instruction and Training: Instructions to subjects are printed on the screen and are as follows:

> "The Dichotic Listening Test consists of a series of letters and digits which are presented to each ear through headphones. During the test, your task will be to concentrate your attention on the letters and digits you hear in a particular ear and to record only the digits heard in that series. The ear you must concentrate on is called the 'target ear' and will be clearly identified 'right' or 'left' before each series begins."
>
> "Now, to better familiarize yourself with the test, put on your headphones and listen to a practice trial. Listen for the command 'right' or 'left'. Then, listen for the digits interspersed among the letters coming through that particular ear. The tape will begin momentarily."

(Have subjects put headphones on with red tag on right ear. Begin with practice trial one).

> "The 'right' or 'left' command that you heard at the onset of each series identified the ear you would have concentrated on

during an actual test trial. Did you hear the digits embedded in the string of letters?"

"Okay, you will now actually do practice trials 1 and 2. Press the numbered key on the keypad that corresponds to the digits you hear through the target ear. Remember to record only the digits you hear, and that o is not a zero (0). Let me repeat that o is not a zero.

Try the first two practice trials. Afterward, you will be presented with a set of three multiple choice questions, answer them as best you can, and then we will discuss any problems you have."

Multiple Choice questions are to be printed on the screen; circles indicate correct answers.

Note: If the subject answers correctly, the screen changes to the next question; if incorrect, it prints "call the test administrator."

When taking the dichotic listening test, you hear "Test 9" and then "Right," you should:

1. Report the numbers and letters on the Right ear.
2. Report the numbers on the Right ear.
3. Report the numbers and letter "0" on the Right ear.

- Press the key corresponding to the correct multiple choice answer.

Halfway through the test trial #9, you hear the command "Left," you should:

1. Continue reporting numbers and letters on the Right ear.
2. Continue reporting numbers only on the Right ear.
3. Switch attention to the Left ear channel and report numbers and letters.
4. Switch attention to the Left ear channel and report numbers only.

- Press the key corresponding to the correct multiple choice answer.

About "0" and "Zero," you should:

1. Report "0"s but not "Zeros."
2. Report "Zeros" but not "0"s, since "0"s are letters.
3. Report both "0"s and "Zeros".

- Press the key corresponding to the correct multiple choice answer.

At the end of the two trials, stop and review the subject's performance, and answers to questions.

Note: Three correct answers set the screen display to the following:

"Now, complete the next four practice trials. After these are completed, immediately prepare for a regular test series of 36 trials. We will start the test now. The test will take approximately twenty minutes."

"Standby."

The six practice trials followed by 36 test trials lead to stabilized performance.

25. Title: Sternberg-Tracking Combination Construct: Time-Sharing Ability (Dual-Task Paradigm)

Task Description: This dual-task performance test (Wickens and Sandry, 1982) represents a combination of the Memory Search Task (visual or auditory fixed set) and the Critical Instability Tracking Task (i.e., UTC-PAB tests #9 and #22 respectively). This combination requires simultaneous execution of responses as described for each task. However, all subjects will be required to track with their left hand and respond to the memory search task with their right. Response equipment is the same as under single-task conditions.

The subject initiates the start of the task after viewing the memory set (from the Sternberg task). After the last element of the set has been displayed and erased, there is a two second pause followed by concurrent presentation of the tracking task and probe stimuli. The memory search stimuli are presented just above the tracking symbol which is centered horizontally on the screen. The trial lasts until the last memory search probe is presented. Both speed and accuracy are emphasized and subjects are told that both tasks are equally important.

Technical Specifications: Stimulus and response parameters match the single-task conditions. When the positive set is displayed, all numbers should be presented simultaneously with 1.5 seconds allowed per item. Sternberg task stimuli are centered in the middle 1/3 of the video display screen and above the tracking-task stimuli (which are displayed in the lower 1/3 of the screen). The software configuration allows the experimenter to define the tracking portion of the task independent from the memory search. The variables for the tracking task are the same as those described in the single-test condition. The experimenter also defines the memory search

variables which include: memory set size, stimulus type, number of stimuli in the positive and negative sets, and the interstimulus intervals.

Data Specifications: Raw data collection (for the tracking task) include average RMS error, the final lambda value, and the the total number of boundary hits. For the Sternberg task, percent error, average correct reaction time, and average incorrect reaction time must be obtained. Other Sternberg task data include the cumulative testing time (in ms), the probe presented, the correct response, and the subject response. Standard summary statistics are listed under the headings Positive, (Correct-Incorrect), Negative, (Correct Incorrect), and Overall for the following: mean reaction time, standard deviation, number of probes, percentages, time-out errors and out-of-bound errors.

Instructions and Training: Instructions are: "Now you will perform a memory and tracking task at the same time. The memory task will be performed with your right hand, and the tracking task will be performed with your left. Both tasks are equally important. Try to respond as quickly and accurately to the memory task as possible while tracking as well as you can. Each trial will last 90 seconds. There will be a 30 second break between each trial."

Training requirements: The tracking task and the Sternberg task must each be practiced alone until performance has begun to asymptote. At best, initial dual-task performance is normally extremely erratic. Subjects should be required to practice this combination for several sessions (enough to establish stability of performance) prior to actual data collection.

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19 ABSTRACT (Continue on reverse if necessary and identify by block number)

The Unified Tri-service Cognitive Performance Assessment Battery (UTC-PAB) represents the primary metric for a Level II evaluation of cognitive performance in the JWGD3 MILPERF chemical defense biomedical drug screening program. Emphasis for UTC-PAB development has been on the standardization of test batteries across participating laboratories with respect to content, computer-based administration, test scoring, and data formating. This effort has produced a 25-test UTC-PAB that represents the consolidation and unification of independent developments by the Tri-service membership. Test selection was based upon established test validity and relevance to military performance. Sensitivity to effects of hostile environments and sustained operations were also considerations involved in test selection. Information processing, decision-making, perception, and mental workload capacity are among the processes and abilities addressed in the battery.

The UTC-PAB represents a dynamic approach to battery development. The nature of the biomedical drugs screened and information from performance centered task analyses will direct the form of future versions of the battery.

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