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16. Abstract

Factor analyses were performed on data from 51 subjects tested on the CAMI Multiple Task Performance Battery (MTPB). Five different complex performance task combinations were used as well as the six individual MTPB tasks performed by themselves. The primary treatment of the data involved factor analyses of the tasks of the five different complex tasks along with appropriate measures of the tasks performed singly. The results were interpreted to support the hypothesized existence of a time-sharing ability. Orthogonal factors were found on which the monitoring tasks, in general, loaded during simple performance; the monitoring tasks loaded on separate orthogonal factors when they were performed as a part of a complex task. Potential relevance of these findings to aviation selection and performance research programs is noted.

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TIME-SHARING ABILITY IN COMPLEX PERFORMANCE: AN EXPANDED REPLICATION

I. Introduction.

In an earlier study, Jennings and Chiles (1) defined the concept time-sharing ability as being "a reliable source of variance that contributes to performance of complex tasks but is independent of simple-task performance of the constituent tasks." The results of factor analyses applied to data collected on tasks performed both singly and as part of a task complex were found to fit that definition in the case of three monitoring tasks. One of the monitoring tasks involved response to the onset of any one of five red lights; there was one light at each corner of the subject's panel and one light in the center. A second monitoring task involved response to the offset of any one of five green lights that were physically paired with each of the red lights but programed independently. The third monitoring task involved the detection of a shift in the average position of a "randomly" fluctuating meter from a normal value of zero to a value of plus or minus 25; the maximum pointer excursion for a meter without a signal present was ± 25; detection of a signal was indicated by the subject's throwing a three-position, spring-loaded-to-center lever switch in the direction in which the subject thought the average position had shifted; immediate feedback was given by the stopping of the pointer on its "true" average value. Six of the tasks were used to construct two complex tasks. The light-monitoring tasks were performed singly as were a mental arithmetic task and an elementary, group problem-solving task; the mental arithmetic and problem-solving tasks were also performed concurrently with the lights task to form the first complex task. A second complex task was made up of the meter-monitoring task, a pattern discrimination, and a two-dimensional compensatory tracking task; each of these tasks was performed both singly and in combination as a complex task. The findings that are of interest to the present discussion were (i) the three monitoring tasks, when performed under complex conditions, had large loadings on a single factor; (ii) measures from the monitoring tasks when performed under simple task conditions showed small loadings on that factor; (iii) the two light-monitoring tasks had large loadings on another orthogonal factor under simple performance conditions; and (iv) the meter-monitoring task had a large loading on still another orthogonal factor under the simple condition. It was concluded that the results support the hypothesis that there is in fact a complex-monitoring ability that could reasonably be called a time-sharing ability. However, the number of subjects per measure, 39 subjects and 22 measures, was substantially smaller than is generally regarded as adequate for purposes of factor analysis. For this and other reasons, Jennings and Chiles stated that ". . . this type of study requires replication before final acceptance of the validity of the concept of time-sharing is warranted." The present study was undertaken to provide such a replication and to provide a wider range of complex tasks (i.e., a greater number of task combinations) and a somewhat greater number of subjects. A more complete rationale for the study is presented in that earlier report and, therefore, will not be repeated here.

II. Method.

A. Subjects. The data from a selected sample of 51 male volunteers in their twenties, who were paid for their services, were used in the analyses of the experimental results; 21 subjects were tested but not included in the analyses because of missing data and/or failure to follow instructions.

B. Apparatus. The CAMI Multiple Task Performance Battery (MTPB) was used in this research. The MTPB consists of six tasks that can be programed independently across subjects; up to five subjects can be tested at a time. The tasks can be presented in any combination of from one to six tasks simultaneously. The MTPB system is computerized so that all signals, problems, etc., are presented and scored automatically under computer program control. The raw data are stored on magnetic tape for later, off-line analyses. Brief descriptions of the nature and performance demands of the tasks follow.

1. Red and green lights monitoring (Red Lights and Green Lights). At each corner and in the center of the subject's panel are located pairs of integral lights/switches. The upper light/switch of each pair is red and the lower one is green. The normal state is for the green lights to be on and the red lights to be off. A signal consists of a change of state of a light and response is made by pushing the light/switch; this returns the light to its normal state and a computer record is generated that reflects the information necessary to identify the light and subject involved, the time of onset (or offset), and the time at which the response is made (or, if no response is made, the time of automatic return of the light to its normal state); response time is recorded in milliseconds separately for the red and the green lights. On the average, a signal (either red or green) is introduced once each minute; signals that are not responded to are removed after 15 seconds.

2. Meter monitoring (Meters). The displays for this task consist of four edge-reading meters having full-scale values of +50 and -50. A signal on this task consists of the deflection of one of the meters by a controllable amount either to the right or to the left of center, the zero point. Response is made by depression of one of the two buttons below each meter that is on the side toward which the meter had deflected. If a correct response is made, the signal is removed and the pointer returns to the zero (average) position when the button is released. The apparent difficulty of the task can be varied from very easy (i.e., a signal can be detected at a glance) to very difficult (i.e., rather careful observation of the meter is required for 1 or more seconds) by the introduction of a "random" background disturbance. When the background disturbance (noise) is introduced, the pointer wanders about unpredictably with an average position of zero if no

signal is present. With the addition of a signal, the pointer behavior continues as before but with an average position that has shifted either to the right or to the left of center. When a button for a given meter is depressed, the background noise is removed and the pointer stops on its "true" average value, thus giving immediate feedback as to the accuracy of the response. When the button is released, the background noise is again added to the pointer movement. In this study, the amplitude of a signal was set equal to the approximate maximum excursion of the pointer when driven by noise alone. Thus, fairly frequent readings beyond the normal maximum in either direction were clear evidence of the presence of a signal. Signals, introduced at an average rate of one each minute, were distributed unpredictably across displays and across time. A signal, when presented, remained until responded to or until replaced by a new signal. The response time for a given signal was computed in milliseconds on the basis of the time the signal was introduced; however, if the subject had not responded to the preceding signal, the time at which that signal was introduced was used in computing the response time to the later signal; this procedure was extended back in time to include all contiguous, not-responded-to signals in calculating the response time on this task. Thus, the number of signals presented in a given session was, for computational purposes, determined by the number of signals to which the subject had responded correctly.

3. Mental arithmetic (MATH). The display for this task is a 256-character (32 characters/row by 8 rows) Burroughs self-scan display. Characters are formed at a given character position by the illumination of configurations of dots in each 5-dot-wide (46 mm) by 7-dot-high (67 mm) matrix. Actually, only the bottom row of characters is used to present the arithmetic problems. A typical problem might be: 57 + 29 - 45 = ? (answer: 41). The subject enters the answer by using a reverse-order serial entry keyboard; it requires that the least significant digit be entered first. Thus, for the above problem, the subject first enters the number 1, which appears in the extreme right-hand cell of the bottom row; next, he enters the number 4 and it appears in the cell that is second from the right in that row. Two correction buttons are provided, one for "erasure" of the last digit entered and one for erasing all digits entered. When the subject has entered what he considers to be the correct answer, he depresses a "complete" button. At that time, the accuracy of the answer is determined and, if it is correct, an "R" appears in the cell second from the right of the top row of the display. If the answer is wrong, a "W" appears at that location; simultaneously, the problem and answer are removed from the display. The problem elements in this study could take any value from 11 through 99; they were selected so that neither of the "plus" elements would be the same as the "minus" element and the problems were constructed so that approximately half the answers would be greater than 100 and half less than 100. Time from the introduction of the problem until depression of the "complete" button is measured in milliseconds. Problems are presented at 20-second intervals. Accuracy (correct answers/total problems presented) was used as the single measure of MATH performance.

4. Pattern discrimination (PD). The upper-left six-character by six-row portion of the Burroughs self-scan display is used to present problems on this task. For a given character position in this matrix, all the dots in a 5-dot by 7-dot matrix can be illuminated to form a lighted rectangle. These lighted rectangles are then used to form vertically oriented bargraphs with each column height from one through six appearing just once. The problems on this task are analogous to a question on a multiple-choice examination. The first pattern presented for a given problem is the standard or "question" pattern. This pattern is followed by two comparison patterns that yield three possible answers: (i) one of the comparison patterns might be the same as the standard; (ii) two (both) comparison patterns might be the same as the standard; or (iii) neither comparison pattern might be the same as the standard. The subject indicates his answer by depressing one of three switches labeled "1," "2," and "N." On entering his answer, which is not acknowledged by the system unless made after the onset of the second comparison pattern, the correct answer appears in the extreme upper-left-character position of the display. The timing sequence for this task is as follows: the standard pattern appears for 5 seconds and each comparison pattern appears for 2 seconds with 1 second between patterns; there is a 15-second "off" period after the offset of the second comparison pattern. Thus, problems are presented every 30 seconds on this task. Both speed of response (measured in milliseconds from the onset of the second comparison pattern) and accuracy can be recorded, but in this study, accuracy was used as the single measure of performance.

5. Problem solving (PS). Each subject's test panel is equipped with five pushbutton switches, a white "task active" light, and three "feedback" lights. The task requires the subject to discover the correct sequence in which to press the buttons in order to turn on a blue feedback light that signifies the problem has been solved. Anytime a button is pushed, an amber light is illuminated to show that the response has been acknowledged by the system. A red light provides error feedback. The subjects are instructed to follow a standard search procedure, always beginning with the leftmost button and proceeding from left to right. The initial illumination of the white and the red lights indicates to the subject that an unsolved problem is present. Subsequently, the red light provides error information as follows: Anytime any one of the buttons is depressed, the red light goes out. If the button pushed is the correct first response for a given problem, the red light will remain out when the button is released. Thus, the initial step in solving a problem is to push the buttons one at a time until the button is found that, when released, leaves the red light off. The search then continues for the next button; if it is correct, the red light remains out when that button is released; if it is wrong, the red light comes back on and the button previously determined to be the first button must be pushed again to continue the search for the second button in the sequence. The search proceeds in an analogous manner until each of the five buttons has been pushed just once in the correct sequence for a given problem. At that point, the blue light comes on, signifying that the problem has been solved. After a lapse of 20 seconds, the blue light goes out and the

red and white lights come back on; however, this time the onset of those lights indicates that the same problem is being presented a second time. Thus, the subject must remember the correct sequence and cannot (efficiently) solve all problems in a trial-and-error manner without paying attention to which buttons are correct and which are incorrect for a given phase of the solution. After entering the solution a second time and after another lapse of 20 seconds, the blue light goes out and the red and white lights come on, but this time these events signify that a new problem is present. Thus, efficient performance requires that the subject also remember whether a problem is being presented for the first time or is a repetition of the previous problem. Several measures can be derived from this task: (i) the speed of solution of the first presentation of a problem; (ii) the speed of entering the second solution (confirmation); (iii) the occurrence of redundant responses (responses made when information already acquired should make the subject aware that the response being made is not correct); and (iv) errors made on the second entry of the solution. Solution accuracy (PS-Sol) and confirmation time/problem (PS-Conf) were used in the present study. Although the time between the presentations of problems is fixed at 20 seconds, the rate at which the subject attempts to solve the problem is subject paced; the problem remains until solved.

6. Two-dimensional compensatory tracking (TRK). The display for the tracking task is a 7.5-cm oscilloscope cathode-ray tube (CRT) mounted in the upper-center part of the subject's panel. The target on the CRT is a dot of light about 1 mm in diameter, and the center of the CRT is defined by horizontal and vertical crosshairs scribed on a plastic cover in front of the CRT. The subject's task is to use a control stick to attempt to counteract a "randomly" varying disturbance imparted to the dot by the computer and keep the dot as near to the intersection of the crosshairs as possible. The maximum amplitude of the disturbance and the stick gain are set so that appropriate manipulation of the stick can always bring the dot to the center of the screen. Performance of the tracking task is scored by analog circuitry that integrates absolute error and a quantity that is proportional to error squared for each dimension. The integration period is 1 minute, and the computer reads out and records the four error measures for each subject at the end of each minute. The error-squared measure is converted to RMS (root mean square) error and, in addition, vector RMS and vector absolute error measures are derived. Previous research (2) has shown that these measures are all highly intercorrelated; therefore, vector RMS error was used as a single index of tracking performance.

7. Task combinations. For the simple task conditions, each of the six tasks was performed independently for 15 minutes on each of 2 successive days; in addition, the meters- and lights-monitoring tasks were performed simultaneously for two noncontiguous 15-minute periods on each of those 2 days. Five complex task conditions were used, each of which included the meters- and the lights-monitoring tasks; the combinations were (i) problem solving and tracking (PS/TRK), (ii) problem solving and arithmetic (PS/MATH), (iii) pattern discrimination and tracking (PD/TRK), (iv) pattern discrimination

and problem solving (PD/PS), and (v) arithmetic and tracking (MATH/TRK). Each of these combinations was performed for 30 minutes on each of 2 subsequent days. On the mornings of the 2 test days following training, the subjects performed on each of the six simple tasks in a single session of 2 hours' duration. After lunch, the complex tasks were performed in two sessions; combinations (i), (ii), and (iii) were performed as a 90-minute session and combinations (iv) and (v) as a 1-hour session.

On the first day of testing, subjects were given approximately 1 hour of training and orientation with each task introduced by itself; the performance of the subjects was closely observed to insure that the subjects appeared to understand what was required on each task. The subjects were instructed that they were to try to do their best on each task at all times.

III. Results.

Reliability coefficients were calculated for each measure for each performance condition using the Day 1 vs. the Day 2 data. Since the factor analyses were carried out on the means of the 2 days of performance, the Spearman-Brown prophecy formula was used to compute the expected reliability of those means. The resultant coefficients are shown in Table 1. The coefficients for the green lights task were significant for all conditions except the combination involving arithmetic and tracking. Only three of the coefficients were significant for the red lights task: the conditions with problem solving and tracking, pattern discrimination and tracking, and pattern discrimination and problem solving. Two of the reliability coefficients were significant for the meters task; these were the simple condition and the problem solving and tracking condition. All three coefficients were significant for arithmetic, but only one was significant for pattern discrimination--the combination involving patterns and problem solving. All four coefficients for nonredundant responses on problem solving were significant and large, and all four coefficients for second solution-time-per-problem were significant though not as large. All four coefficients for the tracking task were significant though not large. The correlation matrix of all of the measures used in the analyses are shown in the appendix.

Five factor analyses were carried out, one for each of the complex task combinations, to examine the findings for evidence of a time-sharing factor. The data used were the averages across the two trials (one per day) for each measure at a given level of complexity. In all of the analyses, the principal axes method was used with unity in the major diagonal. Factors were extracted in a stepwise procedure until a factor with an eigenvalue of less than 1 was obtained. All factors with eigenvalues greater than 1 were then rotated to simple structure by the normal varimax method. In the case of the simple task conditions, the same data were used in each analysis in which a given measure appeared.

TABLE 1. Day 1 vs. Day 2 Corrected* Reliability Coefficients

Condition	Green Lights	Red Lights	Meters	MATH	PD	PS-Sol	PS-Conf	TRK
Simple Task	.764	.153	.932	.575	.002	.757	.295	.397
PS & TRK	.625	.369	.394	-	-	.882	.425	.605
PS & MATH	.689	-.006	.213	.503	-	.795	.280	-
PD & TRK	.549	.396	.071	-	.239	-	-	.424
PD & PS	.471	.515	.020	-	.587	.887	.616	-
MATH & TRK	-.141	-.004	.209	.724	-	-	-	.497

*Spearman-Brown prophecy formula
$r_{.05} = .273$; $r_{.01} = .354$

A. Problem solving and tracking (PS/TRK). Twelve measures were used in this analysis, six for each level of complexity. The measures were: response times to green lights, to red lights, and to meters; for problem solving, percent nonredundant responses (first solution), and solution-time-per-problem (second solution); for tracking, vector RMS error.

TABLE 2. Factor Loadings for PS/TRK Condition

(S = simple task performance; C = complex performance)

Task	Performance	F1	F2	F3	F4	F5
Green Lights	S	.21	.03	.82	.09	.07
	C	.83	-.17	-.10	-.03	.09
Red Lights	S	.05	.14	.85	.05	-.04
	C	.73	-.13	.44	.19	-.20
Meters	S	-.14	.26	.65	.00	.55
	C	.13	-.06	.03	.05	.94
PS-Sol	S	-.02	-.97	-.09	.07	.02
	C	.03	-.97	-.14	-.11	-.02
PS-Conf	S	.79	.09	.11	.20	.03
	C	.79	.27	.10	.25	.13
TRK	S	.11	-.05	.15	.93	-.06
	C	.45	-.05	.04	.78	.19
Eigenvalue		2.71	2.10	2.10	1.62	1.30

Five factors were extracted with the eigenvalue criterion used. After varimax rotation (Table 2), the first factor was a mixed-loading factor; the second factor was rather strongly an index of nonredundant responding on the problem-solving task; the third factor was primarily a monitoring factor for simple task conditions; the fourth factor was rather clearly a tracking error factor; and the fifth factor was primarily a meter-monitoring factor with a high loading for complex performance and an intermediate loading for simple performance. As regards the time-sharing hypothesis, the first factor, although somewhat heterogeneous, did exhibit properties that would suggest such an ability; it had large loadings for response time to green lights and red lights for the complex condition, and large loadings for time-per-problem on problem solving for both simple and complex performance on the second solution.

B. Problem solving and arithmetic (PS/MATH). Again, 12 measures were used in the analysis with percent correct on arithmetic being used rather than vector RMS error on tracking. Four factors were extracted (Table 3); the first one again was a mixed factor with loadings on arithmetic (simple and complex) and problem-solving time-per-problem both simple and complex for the second solution. The second factor had large loadings on the three monitoring tasks under simple conditions. The third factor was essentially an index of percent nonredundant responses on problem solving, and the fourth factor showed sizeable loadings on the monitoring tasks under the complex condition.

TABLE 3. Factor Loadings for PS/MATH Condition

(S = simple task performance; C = complex performance)

Task	Performance	Factors F1	F2	F3	F4
Green Lights	S	.13	.81	.04	-.24
	C	.17	-.08	.14	-.85
Red Lights	S	.02	.81	-.09	-.03
	C	.19	.30	-.23	-.70
Meters	S	-.05	.78	-.23	.04
	C	.00	.06	-.04	-.65
MATH	S	-.84	-.06	.16	-.07
	C	-.85	-.08	.11	.10
PS-Sol	S	-.11	-.13	.96	.01
	C	-.13	-.11	.94	.11
PS-Conf	S	.78	.17	.10	-.13
	C	.80	-.24	-.11	-.21
Eigenvalue		2.80	2.15	2.00	1.78

C. Pattern discrimination and tracking (PD/TRK). Ten measures were used in this analysis; they were: response times for each of the monitoring tasks, percent correct on the pattern discrimination task, and vector RMS error on the tracking task. Four factors were extracted (Table 4). The first factor showed large loadings on the green lights task under the simple condition and the red lights task under both the simple and complex conditions. The second factor showed a large loading for green lights under the complex condition and tracking under both conditions. The third factor showed large loadings on the meters task under both simple and complex conditions and the fourth factor showed large loadings for pattern discrimination under both conditions. Thus, as regards the hypothesized time-sharing ability, the only suggestive finding was the fact that green lights loaded on different factors for the simple and the complex conditions.

TABLE 4. Factor Loadings for PD/TRK Condition

(S = simple task performance; C = complex performance)

Task	Performance	Factors F1	F2	F3	F4
Green Lights	S	.71	.22	.32	-.11
	C	.26	.64	-.24	-.04
Red Lights	S	.84	-.04	.20	-.05
	C	.85	.12	-.01	-.07
Meters	S	.33	-.05	.84	-.16
	C	.09	.04	.89	-.15
PD	S	-.02	.34	-.11	.93
	C	-.17	-.13	-.18	.89
TRK	S	.12	.88	.12	.02
	C	-.08	.91	.08	-.06
Eigenvalue		2.15	2.08	1.76	1.73

D. <u>Pattern discrimination and problem solving (PD/PS)</u>. Twelve measures were used in this analysis and four factors were extracted (Table 5). The first factor showed large loadings both for red and green lights under the simple condition and for meters under both the simple and the complex conditions. The second factor was a fairly clean index of nonredundant responses on problem solving. The third factor showed large loadings for pattern discrimination under the simple condition and for problem-solving time-per-problem for the second solution for both conditions; it showed an intermediate loading for pattern discrimination under the complex condition. And the fourth factor was primarily an index of red and green lights monitoring under the complex condition.

TABLE 5. Factor Loadings for PD/PS Condition

(S = simple task performance; C = complex performance)

Task	Performance	Factors			
		F1	F2	F3	F4
Green Lights	S	.78	-.09	.11	.32
	C	-.06	-.03	.02	.83
Red Lights	S	.76	.03	.04	-.03
	C	.33	.18	.01	.75
Meters	S	.84	.24	.02	-.11
	C	.80	.24	.04	.13
PD	S	-.23	-.13	-.76	.33
	C	-.01	.19	-.57	.05
PS-Sol	S	-.15	-.95	.00	-.60
	C	-.19	-.95	.01	-.38
PS-Conf	S	.09	.01	.82	.22
	C	-.07	.30	.65	.45
Eigenvalue		2.76	2.09	2.00	1.75

E. Arithmetic and Tracking (MATH/TRK). Ten measures were used in this analysis. They were: green lights, red lights, and meters--both simple and complex; arithmetic percent correct--simple and complex; and tracking vector RMS error--simple and complex. Four factors were extracted. After rotation (Table 6), the first and second factors reflected monitoring under the simple task condition and the complex condition, respectively. The third factor was a fairly pure measure of arithmetic performance both simple and complex. And the fourth factor was a clean measure of tracking with equal loadings for the simple and the complex conditions.

TABLE 6. Factor Loadings for MATH/TRK Condition

(S = simple task performance; C = complex performance)

Task	Performance	Factors F1	F2	F3	F4
Green Lights	S	.81	.22	-.02	.18
	C	-.02	.80	-.06	.29
Red Lights	S	.83	-.03	.02	.06
	C	.22	.79	.05	.09
Meters	S	.80	-.01	.04	-.05
	C	-.04	.74	.29	-.21
MATH	S	-.07	-.03	-.92	-.14
	C	.05	-.17	-.89	-.16
TRK	S	.10	.17	.04	.87
	C	.05	-.05	.38	.80
Eigenvalue		2.03	1.92	1.87	1.60

IV. Discussion.

A. Reliability. Overall, the reliability coefficients for the majority of the task measures were substantially lower than have been found in previous research (1) with these tasks. One likely hypothesis for accounting for this finding is that, compared to our previous work, the test sessions were relatively long (perhaps inducing some variability in attentiveness) and the measurement intervals were relatively short (reducing the number of available observations). The relatively low coefficients for the meter-monitoring measures under all but one of the complex conditions were quite likely the result of the high difficulty level of the task; specifically, the signal-to-noise ratio was low, and subjects got feedback on this task only when they responded. The low coefficients for the pattern task under the simple and the PS/TRK conditions were probably a result of the fact that subjects did well on these tasks overall (means 91.8 and 87.2 percent, respectively), and, therefore, there was little variance on the measure.

Another index of the "reliability" of the measures can be seen in the intercorrelation matrix (see the appendix). In fact it might be argued that the consistency of the measures across task combinations is a better estimate of the reliability of the correlations used in the factor analyses than the Day 1/Day 2 reliability coefficients. Considering the red lights, the measure for each task combination correlates significantly at the .05 level or better with the various green lights measures. Similarly, the correlations among the different task combinations for red lights are also significant at the .05 level or better. Overall, the reliability (or at least the consistency) of the measures taken as a set is considered to be adequate for the purposes of the study.

B. Factor Analytic Findings. The results of the factor analyses for two of the task combinations represent a "clean" replication of the previous results found with the old, electromechanical version of the MTPB (1). This was the combination involving problem solving and arithmetic and the combination involving arithmetic and tracking. In each of these two analyses, two orthogonal factors were found for the three monitoring task measures--one factor for monitoring under the simple condition and another factor for the complex condition. This corresponds directly to the previous findings (1) which were interpreted to suggest that there is a time-sharing (or complex monitoring) ability.

Two other task combinations yielded results that were compatible with the previous findings as well as with the two above-mentioned task combinations. In the case of the condition involving pattern discrimination and problem solving, the two lights-monitoring measures loaded on orthogonal factors for the simple and the complex conditions. However, both the simple and complex meters measures loaded on the factor that represented simple performance for the lights monitoring tasks. There are two points that are of relevance to the behavior of the meters measure; first, the predicted reliability of the complex meters measure was .02 (based on the Day 1/Day 2 correlation), and, second, the correlation between the simple meters measure and this particular complex meters measure was .84. Considering these two points, it is not surprising that both meters measures loaded on the "simple monitoring" factor. In the case of the task combination involving problem solving and tracking, again the simple and complex lights-monitoring measures loaded on different factors and again the meters measures were somewhat aberrant. In this case, however, the simple meters measure loaded on the simple lights-monitoring factor, but the complex meters measure loaded on a separate, orthogonal factor which also showed an intermediate loading for the simple meters measure. The reliability of the complex meters measure for this condition, though not exceptional (predicted r = .394), was the most reliable of the measures of meters performance under any of the complex conditions. No good explanation of this finding for meters in this factor analysis suggests itself.

The final task combination, pattern discrimination and tracking, fits with the previous findings and the other analyses of the present study only in that the green lights measure loads on different factors for the simple and the complex conditions. The red lights measure showed essentially zero reliability under the complex condition, and, since the correlation between this measure and the simple measure was .58, it would be expected that they would load on the same factor; as it turned out, this was the factor that the simple green lights measure loaded on. 1.

There were several other findings from the factor analyses that are of interest as regards the tasks of the MTPB. First, in each of the analyses for the combinations involving problem solving, the measure of percent 2. nonredundant responses on problem-solving first solutions (for both simple and complex performance) loaded on an essentially "pure" factor. The second solution measure of time-per-problem was somewhat capricious; it loaded on arithmetic when performed with arithmetic, on pattern discrimination in that combination, and on complex monitoring in the combination involving tracking. Vector RMS tracking error loaded on a "pure" factor when tracking was performed with arithmetic and with problem solving and on the same factor as complex green lights in the combination involving pattern discrimination. Pattern discrimination and arithmetic each loaded on "pure" factors when performed with tracking, but when they were each performed with problem solving, they each shared a factor with a problem-solving measure--time-per-problem on second solutions. It should be noted that in the present study problem solving was an individual task whereas in the earlier study it was a group task. Therefore, the measures in the present study should have been less subject to contamination from errors resulting from the assignment of subjects to test groups.

V. Summary and Conclusions.

Fifty-one subjects were tested on the CAMI Multiple Task Performance Battery under conditions that permitted an examination of the possible existence of a "time-sharing ability" across a total of five complex task combinations. Factor analyses of two of the task combinations gave clear-cut support for the earlier results reported by Jennings and Chiles (1); the study found "a reliable source of variance that contributes to performance of complex tasks but is independent of simple-task performance of the constituent tasks." The factor analyses of two task combinations also supported this finding and one gave support to the earlier finding. It is concluded that the present and the earlier study suggest that assessment of complex performance ability should be a consideration in research on the selection of personnel for aviation jobs requiring complex performance as well as in the development and selection of research tasks to be used in evaluating changes in operating procedures or the acceptability of taking various kinds of medications while performing aviation-related (as well as other kinds of) duties.

References

1. Jennings, A. E., and W. D. Chiles: An Investigation of Time-Sharing Ability as a Factor in Complex Performance, HUMAN FACTORS, 19(6):535-547, 1977.

2. Jennings, A. E., W. D. Chiles, and G. West: Methodology in the Measurement of Complex Human Performance: Two-Dimensional Compensatory Tracking, FAA Office of Aviation Medicine Report No. AM-72-21, 1972.

APPENDIX

Complete Correlation Matrix
(N = 51)

Task	Condition																																				
Green Lights	Simple	1.0																																			
	PS/TRK	.16	1.0																																		
	PS/MATH	.24	.46	1.0																																	
	PD/TRK	.26	.56	.55	1.0																																
	PD/PS	.16	.52	.65	.58	1.0																															
	MATH/TRK	.21	.54	.70	.64	.72	1.0																														
Red Lights	Simple	.54	-.11	-.06	.06	-.20	-.07	1.0																													
	PS/TRK	.43	.62	.46	.58	.30	.40	.40	1.0																												
	PS/MATH	.42	.39	.45	.51	.31	.30	.25	.53	1.0																											
	PD/TRK	.48	.39	.27	.21	.07	.40	.58	.47	.50	1.0																										
	PD/PS	.45	.36	.47	.41	.44	.47	.34	.57	.55	.55	1.0																									
	MATH/TRK	.29	.30	.31	.34	.34	.51	.24	.41	.31	.40	.78	1.0																								
Meters	Simple	.52	-.18	-.12	-.05	-.02	.07	.04	.06	.19	.22	.11	.07	1.0																							
	PS/TRK	.09	.21	.29	-.06	.10	.20	.08	-.01	.16	.07	-.04	-.06	.40	1.0																						
	PS/MATH	.08	.22	.33	.11	.22	.22	.12	.04	.32	.08	-.01	-.09	.13	.58	1.0																					
	PD/TRK	.28	.15	.38	-.06	-.08	.11	.21	.14	.20	.18	.03	-.03	.68	.69	.44	1.0																				
	PD/PS	.30	-.05	.07	.07	.15	.27	.40	.10	.25	.20	.29	.36	.04	.39	.23	.69	1.0																			
	MATH/TRK	.10	.16	.17	.08	.32	.40	-.04	.02	.04	-.03	.12	.39	.00	.05	-.08	-.03	.29	1.0																		
PO	Simple	-.17	.05	.19	.04	.13	.14	-.14	-.14	-.12	-.03	.13	.20	-.28	.04	-.02	-.17	-.18	.02	1.0																	
	PD/TRK	-.25	-.21	.08	-.12	-.05	-.11	-.18	-.39	-.20	-.27	-.04	.00	-.29	-.14	-.03	-.36	-.29	-.19	.72	1.0																
	PD/PS	.08	-.29	-.08	.03	-.02	-.08	-.01	-.20	-.12	-.21	-.10	-.04	.05	.06	.03	-.07	-.02	-.07	.36	.57	1.0															
Math	Simple	-.11	-.05	.08	-.24	-.06	-.05	-.04	-.15	-.22	.01	-.02	-.10	-.06	.07	-.11	-.04	-.16	-.20	.32	.27	.11	1.0														
	PS/MATH	-.09	-.30	-.19	-.31	-.17	-.25	-.10	-.38	-.29	-.10	-.25	-.21	-.08	-.06	-.19	-.14	-.15	-.08	.26	.30	.38	.78	1.0													
	MATH/TRK	.02	.08	.03	-.24	-.07	-.15	-.08	-.09	-.16	.14	-.11	-.22	.02	.15	.05	.12	-.08	-.27	.14	.16	.23	.74	.71	1.0												
PS-Sol	Simple	-.10	.10	.09	.02	.08	.01	-.20	.04	-.27	-.10	-.28	-.27	-.28	.05	-.02	-.04	-.28	-.07	.12	.02	-.12	.23	.21	.16	1.0											
	PS/TRK	-.16	.14	.09	.02	.02	.03	-.25	.05	-.24	-.11	-.30	-.32	-.32	.00	.03	-.08	-.33	-.06	.13	.03	-.16	.20	.16	.14	.95	1.0										
	PS/MATH	-.13	.09	-.02	-.03	.08	-.04	-.19	.02	-.20	-.14	-.32	-.26	-.27	.00	-.09	-.11	-.28	.03	.19	.12	-.09	.20	.18	.10	.90	.94	1.0									
	PD/PS	-.09	.19	.14	.06	-.01	.09	-.17	.09	-.23	-.10	-.30	-.27	-.37	.04	-.03	-.14	-.34	.03	.16	.09	-.08	.20	.19	.17	.91	.93	.91	1.0								
PS-Conf	Simple	.22	.43	.24	.33	.11	.16	.17	.54	.19	.24	.18	.10	.07	.08	.10	.23	.07	-.13	-.47	-.51	-.22	-.45	-.56	-.14	-.04	-.03	-.12	.01	1.0							
	PS/TRK	.28	.42	.26	.30	.15	.20	.10	.47	.26	.29	.27	.29	.11	.18	-.07	.23	.26	.34	-.37	-.54	-.21	-.46	-.46	-.24	-.20	-.20	-.21	-.07	.72	1.0						
	PS/MATH	.06	.42	.35	.42	.19	.27	-.14	.31	.23	.11	.21	.20	-.22	-.06	-.01	-.05	-.05	.17	-.23	-.35	-.22	-.55	-.53	-.35	-.16	-.13	-.25	-.09	.63	.75	1.0					
	PD/PS	.15	.37	.26	.43	.29	.30	-.03	.29	.24	.10	.24	.22	.01	-.04	.12	.09	.17	.20	-.26	-.30	-.11	-.59	-.51	-.37	-.24	-.19	-.28	-.22	.61	.65	.74	1.0				
TRK	Simple	.23	.15	.19	.37	.30	.25	.15	.37	.29	.26	.41	.24	.05	.03	-.06	.14	.18	.04	.01	-.15	-.06	-.18	-.20	-.20	.09	.00	-.02	.02	.22	.29	.20	.20	1.0			
	PS/TRK	.23	.37	.41	.42	.43	.36	.10	.45	.25	.26	.36	.17	.04	.26	.19	.19	.09	-.04	-.10	-.27	-.07	-.27	-.40	-.26	.07	.05	-.02	.03	.52	.48	.31	.49	.67	1.0		
	PD/TRK	.19	.11	.14	.41	.36	.26	-.01	.28	.18	.03	.31	.08	.01	-.08	-.01	.07	.05	-.10	-.07	-.13	.03	-.22	-.24	-.27	.06	.04	-.03	-.04	.26	.16	.30	.37	.74	.72	1.0	
	MATH/TRK	.17	.10	.15	.30	.32	.19	.09	.30	.28	.22	.25	.03	.05	-.11	.09	-.02	.01	-.01	-.21	-.34	-.15	-.41	-.43	-.41	.01	.02	-.08	-.11	.24	.18	.38	.46	.55	.66	.72	1.0

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