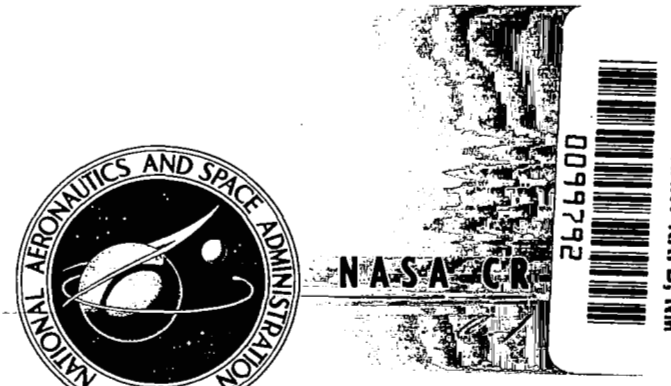


NASA CONTRACTOR REPORT

NASA CR-335



# DEVELOPMENT OF TESTS FOR MEASUREMENT OF PRIMARY PERCEPTUAL-MOTOR PERFORMANCE

*by James F. Parker, Jr., Raymond E. Reilly, Richard F. Dillon, Thomas G. Andrews, and Edwin A. Fleishman*

Prepared under Contract No. NAS 9-2542 *by*
BIOTECHNOLOGY, INC.
Arlington, Va.
*for Manned Spacecraft Center*


NATIONAL AERONAUTICS AND SPACE ADMINISTRATION - WASHINGTON, D. C. - DECEMBER 1965

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## SUMMARY

This study is concerned with the development of a prototype battery of tests which can be used to measure the primary dimensions of perceptual-motor performance. These tests will be of value in assessing the influence of weightlessness and other aspects of the space environment on human performance.

Phase I of this project consisted of an extensive survey of the technical literature concerning perceptual-motor performance. Particular attention was given to factor-analytic investigations leading to the specification of orthogonal abilities underlying complex perceptual-motor performance.

In Phase II an analysis was made of the duties and tasks likely to be required of personnel in space stations and vehicles. Based on the results of Phases I and II, eighteen ability factors were selected as being of sufficient importance to warrant inclusion in the test battery.

Phase III was devoted to the development of an integrated console which would provide separate measures for each of the eighteen perceptual-motor performance dimensions. Every effort was made to keep the console as compact and lightweight as possible.

Phase IV included the refinement of testing procedures and the collection of performance data on a small sample of male subjects.


## INTRODUCTION

The planning and successful accomplishment of extended space missions rests largely upon the availability of a fund of basic information encompassing a number of technologies. In the field of propulsion techniques, for example, information is being developed concerning the characteristics of ion-plasma engines, nuclear reactors, and gas jet engines. The selection of an efficient propulsion system for interplanetary ventures, such as the Mars mission, will be possible with a continuing increase in the extensiveness of basic data concerning the operating characteristics of these engines.

With respect to man, a great deal already is known concerning means of maintaining proper physiological functioning within the space environment.

However, at this time only limited information is available concerning man's performance capabilities in space and the manner in which these capabilities might be altered during extended missions. Benson (1961) comments on this situation as follows:

> One can say with confidence that we now possess all the basic knowledge required to keep man alive in space for a limited, yet significant, period of time. Although there is room for refinement and simplification, and although the development of equipment continues to pose difficult problems, all the essential knowledge is at hand. By contrast, our position with respect to man's behavioral capabilities in space is not nearly so well-established.

One of the primary reasons for the development of the LORL (Large Orbital Research Laboratory) space station by NASA is to provide a vehicle within which extensive investigations can be made of man's performance capabilities in space. In order to achieve maximum utility, this research should deal with human performance at a quite basic level. Such research should result in information concerning the manner in which primary human abilities underlie the more sophisticated performances required in space. In addition, information should be obtained as to the influence of the space environment on the proficiency with which these abilities are used.

## Purpose

This project is concerned with the development of a small battery of tests to measure the primary dimensions of perceptual-motor performance. Through use of this battery, investigations can be made of behavioral proficiency along these basic dimensions. It is anticipated that the performance of astronauts will be measured under the normal one-g environment, upon initial entry into space, and following an extended period of residence in space. In this manner a systematic assessment can be made of the influence of weightlessness and other features of the space environment on man's work capabilities.

This project was divided into four phases. The four phases were as follows:

## Phase I

The first phase of this project consisted of a review and analysis of the technical literature on studies of perceptual-motor performance. Primary attention was given to factor-analytic investigations. The development of a test battery on the basis of factor analysis techniques represents a logical and systematic approach to the construction of performance measures. The use of tests of known factorial structure will allow one to obtain relatively pure measures of those primary perceptual-motor abilities which have been found in previous experimental investigations to be required by more complex tasks. The value of such a test battery is considerable. One can now obtain measures of the basic and independent dimensions of perceptual-motor performance. Thus, many independent variables, such as the varied stresses imposed by space flight, can be realistically compared in terms of their relative effect on this important class of human behavior.

## Phase II

Within this phase, an analysis was made of activities likely to be required of personnel operating in space vehicles. This information formed a basis for selecting among the particular ability dimensions defined in Phase I. In the final effort of Phase II, a tentative design was developed for a test to measure each selected ability dimension.

## Phase III

This phase involved the development of a battery of perceptual-motor tests to measure the primary dimensions selected in Phase II. These tests were integrated into a single console built to resemble, to some extent, an aircraft cockpit or the control station of a space capsule. The individual being tested thus may follow a programmed performance script. During this time separate measures of his performance on each individual test are obtained and recorded.

## Phase IV

This phase consisted of the administration of the perceptual-motor battery to a sample of ten healthy adult males in order to design the instructions and scoring schemes, and to obtain preliminary standardization data under conditions of unit-g.

# IDENTIFICATION AND CLASSIFICATION OF PERCEPTUAL-MOTOR ABILITIES

The first objective of this study was to define a set of basic perceptual-motor ability dimensions. To accomplish this a search was made of the technical literature for studies which indicate in some manner the operation of basic ability dimensions. This literature search was not restricted at this time to those abilities which might be related to space performance but was left open for any ability which might be considered as perceptual or motor in nature. Those abilities considered to be primarily cognitive or sensory, however, were excluded from consideration. On this basis reasoning and decision-making abilities were not included. The same was true for those abilities used in the visual performances required in space. Although such abilities are of unquestioned importance to space activities, their consideration was not within the scope of this project.

## Source Material

Four classes of studies were considered during the technical literature search. Studies within each class were examined carefully to see if the results gave any indication of the operation of a basic ability. Although the probabilities of a successful search varied considerably from one class to another, it was felt that coverage of these four classes would be sufficiently comprehensive. The following classes of studies were examined:

### 1. Factor-Analytic Studies

These studies, the primary aim of which is to define a set of basic abilities underlying performance in more complex tasks, represent the principal source of information. Results of the search of factor-analytic studies were tabulated and are presented as Appendix A. Within this appendix, comparisons can be made among those studies which identify the same ability dimensions. In this manner, some indication can be obtained as to the stability of a given ability as it appears in similar task performances. Appendix A also gives insight into the factorial purity of specific reference tests used in the definition of a factor.

### 2. Studies Involving Correlation or Regression Analysis Models

Studies covered here were those which used individual difference data to demonstrate a relationship between task performance and particular

characteristics of individuals, especially those characteristics which might suggest the operation of some rather basic ability. A study by Dinnerstein, Blitz, and Lowenthal (1964) provides an example. In this investigation, what might be considered as a basic ability (speed of perception) was related to a measure of behavioral proficiency (performance on a complex visual task).

3. Control Dynamics Studies

This section covered "task-oriented" studies, and in particular those which determine the influence of changes in control dynamics upon performance in a continuous control task. Birmingham and Taylor (1954), through use of an engineering analogy, suggest that the control of vehicles of varying dynamic complexity may tap a hierarchy of abilities. Thus, use of position, rate, and acceleration control systems would, in terms of their analogy, require characteristically different transfer functions for the tracker and in turn would bring different abilities into operation.

4. Physical Proficiency Studies

This area includes studies dealing with the dimensionality of physical fitness or physical proficiency. Inasmuch as many of these studies used a factor-analytic approach there was some overlap with the first area described above.

## Assumptions Underlying Literature Search

As indicated, the present study deals with results of a number of laboratory investigations. The following two assumptions are inherent in the use of such information:

1. The types of criterion tasks used in laboratory investigations, and in particular, in factor-analytic studies, are reasonable in terms of real world performances. Stated differently, does performance on a laboratory task such as the Discrimination Reaction Time Task (DRT) resemble any of the performances required, for instance, in the operation of the Gemini Control Panel? The answer seems to be affirmative. Many of the switching operations made in response to visual signals or to patterns of visual signals are quite similar to those required by DRT.

2. In factor-analytic investigations, the types of tests included in reference batteries are reasonable in terms of tapping those abilities which underlie the criterion task. For the most part, a factor analysis study will be successful only to the extent that the investigator has hypothesized an appropriate set of underlying abilities and has included tests to measure these abilities within the reference battery. Since, in most studies of this type, performance on tests within the reference battery is shown to account for some significant portion of criterion task performance, this assumption appears justified.

## Listing of Perceptual-Motor Abilities

On the basis of a systematic search of the technical literature within the four areas described previously, a number of basic perceptual-motor abilities were identified. These abilities were readily classified into six categories. These categories are presented below with a listing of those abilities which fall within each category. A later section of this report describes each ability in detail.

### Category I. Fine Manipulative Abilities

These are the abilities which underlie wrist-finger motions used in manipulating controls.

1. Arm-Hand Steadiness
2. Wrist-Finger Speed
3. Aiming
4. Finger dexterity
5. Manual dexterity

### Category II. Gross Positioning and Movement Abilities

These abilities would be used in reaching for and grasping particular controls.

1. Position estimation
2. Kinesthetic discrimination
3. Response orientation
4. Control position
5. Multilimb coordination

6. Speed of arm movement
7. Position reproduction

Category III. System Equalization Abilities

These are the abilities used in manipulating a control appropriately in response to a dynamic display signal.

1. Movement analysis
2. Movement prediction
3. Rate control
4. Acceleration control

Category IV. Gross Body Movement Abilities

These abilities are involved in shifting position of the entire body.

1. Extent flexibility
2. Dynamic flexibility
3. Static strength
4. Dynamic strength
5. Explosive strength
6. Trunk strength
7. Balance (Gross body equilibrium)
8. Stamina (Cardiovascular endurance)
9. Gross body coordination

Category V. Perceptual-Cognitive Abilities

This category includes nonmotor abilities which have been found to relate to performance on motor-tasks. Typically, however, they account for only a relatively small proportion of criterion variance.

1. Spatial orientation
2. Perceptual speed
3. Visualization

4. Verbal comprehension
5. Mechanical experience
6. Numerical facility
7. Time sharing

Category VI. Reaction Time Ability

This is a single ability found to underlie all of the above performance areas.

## SELECTION OF FACTORS FOR STUDY

Following the identification of a comprehensive list of perceptual-motor abilities it next was necessary to select from this list those factors for which an attempt would be made to develop performance tests. One of the principal criteria used in the selection of factors for retention was that they should conform to the scope of this project. This project is concerned primarily with the development of equipment with which to study the effects of the space environment on human performance. Within this framework, however, it is limited to those performances which would be required in the operation and control of space vehicles. It is not concerned with problems of entering and leaving the vehicle or other extravehicular activities. It was on this basis that the physical proficiency abilities of Category IV: "Gross Body Movement Abilities" were eliminated.

Certain additional factors were eliminated from consideration because of obvious problems which would be encountered in the development of instrumentation. On this basis, for example, the factor "Kinesthetic Discrimination" was excluded. Two other factors, "Visualization" and "Spatial Orientation", were dropped as being primarily cognitive rather than perceptual-motor in nature.

A total of eighteen factors finally were selected for inclusion in the test battery. These eighteen factors are described in detail later within this section.

### Analysis of Space Tasks

Although the basic objective of this study was conceived of broadly as relating to the study of human performance in space, it is obvious that there should be some correspondence between those performances selected for study and those which actually will be required of persons operating in space vehicles. In order to obtain information concerning activities which will be performed by space personnel, a number of individuals within the National Aeronautics and Space Administration were interviewed. The consensus was that the activities required during a Gemini mission, including rendezvous and docking, are representative of the type of activities which will be involved in the operation and control of any space vehicle. In addition, more is known at this time concerning the Gemini mission than any other programmed space voyage. Accordingly, a complete task analysis was prepared for a Gemini mission using information supplied by NASA. This task analysis is presented as Appendix B.

The Gemini task analysis provides a point of departure for the consideration of space activities. Within this project, no factors were excluded simply because they did not appear to be involved in the specific tasks of the Gemini mission. However, in discussing the manner in which each ability factor might be used in space, Gemini performances are used as illustrative material.

## Description of Selected Factors

The following factors were selected as representing important perceptual-motor ability dimensions for which it would be desirable to develop performance tests. A definition is presented for each factor followed by an illustration of the type of space activity which might utilize this ability.

### Category I: Fine Manipulative Abilities

#### Factor 1: Arm - Hand Steadiness

Definition. - This is the ability to make precise and steady arm-hand movements of the type which minimize strength or speed. This ability is involved in tasks requiring maintenance of a steady arm position in space in which the crucial feature is a minimum of tremor as well as in tasks involving steadiness during limb movements.

Related Space Performance. - During the Second Astronaut's sleep period, or in case of an emergency, the First Astronaut may want to set switches on the Second Astronaut's Panel. He has been equipped with an eighteen inch utility pole to make this possible. Effective accomplishment of these activities will require steadiness of the hand and arm.

#### Factor 2: Wrist - Finger Speed

Definition. - This is the ability to make rapid pendular and/or rotary wrist movements involving rapid repetitive jabbing movements in which accuracy is not critical. This ability does not depend upon precise eye-hand coordination.

Related Space Performance. - Although not required in the operation of specific Gemini controls, this ability would be of importance in later space vehicles. For example, the rapid insertion of a large amount of computer-control information through a digital entry keyboard would involve this type of rapid wrist-finger movement.

Factor 3: Finger Dexterity

Definition.- This is the ability to make rapid, skillful, controlled manipulative movements of small objects where the fingers are involved primarily.

Related Space Performance.- Tapping out messages on the Manual Data Keyboard Unit, setting lever-lock toggle switches, and eliminating squelch in the communications system with continuous rotary switches are some of the tasks which may partially involve the use of this ability.

Factor 4: Manual Dexterity

Definition.- This is the ability to make skillful controlled arm-hand manipulation of larger objects.

Related Space Performance.- Manipulating maneuver and attitude controllers, adjusting the mirror, adjusting suit and cabin temperature, fastening and unfastening the seat harnesses, utilizing the abort handle, and secondary oxygen bottle shutoff are typical of tasks which will require manual dexterity.

Category II: Gross Positioning and Movement Abilities

Factor 1: Position Estimation

Definition.- This is the ability to move a limb to a specified position, when the position must be estimated rather than reproduced from an immediately experienced limb position.

Related Space Performance.- The complexity of the Gemini control system frequently requires the astronaut to locate and use controls while his vision is required elsewhere. In such instances the accuracy of control position estimation will bear critically on the contiguity of flight performance.

Factor 2: Response Orientation

Definition.- This is the ability to choose and perform the proper movement or direction of movement from several alternatives. It does not involve interpretation of the spatial characteristics of the stimulus.

Related Space Performance. - Performing the proper control movement to null the Flight Director Indicator or Incremental Velocity Indicator will require the astronaut to select rapidly the proper response pattern. He must, in short, be able to accomplish the proper movement in response to a specific visual signal.

Factor 3: Control Precision

Definition. - This is the ability to make sensitive, highly controlled (but not over controlled) positioning adjustments, primarily where larger muscle groups are involved. These adjustments are made to visual stimuli.

Related Space Performance. - Controlling attitude and translation, particularly during the Terminal and Docking phases of Rendezvous, will require that all controls be manipulated with considerable precision.

Factor 4: Speed of Arm Movement

Definition. - This is the ability of an individual to make a discrete gross arm movement at maximum speed.

Related Space Performance. - Most, if not all, Gemini tasks require a preparatory arm movement to attain a control. While excessive speed will not ordinarily be required, there undoubtedly will be times when tasks will have to be accomplished rapidly. In case of malfunctions or mission abort, arm speed will be particularly important for initiating the proper events.

Factor 5: Multilimb Coordination

Definition. - This is the ability to coordinate the movements of two hands, two feet, or combinations of hands or feet simultaneously.

Related Space Performance. - Both hands will be needed to perform the many tasks required to "fly" Gemini. Although there are no foot controls in the Gemini capsule, the use of two hands at one time may involve the Multilimb Coordination ability. The most extreme, but somewhat improbable, example would be when attitude and translation both are being controlled at once.

Factor 6: Position Reproduction

Definition. - This is the ability to move a limb or a control from a given position and then return to that same position.

Related Space Performance. - The constant changing of attitude control, computer, platform, FDM and FDR modes, and shifting between attitude and

maneuver control requires "the ability to remove one's arm or a control from a position and then to return to that position."

Category III: System Equalization Abilities

Factor 1: Movement Analysis

Definition. - This is the ability to analyze the velocity, acceleration, and higher derivative characteristics of target motion.

Related Space Performance. - The final stage of rendezvous presents the astronaut with a complex visual-motor tracking task. Through use of his attitude and velocity controls he will visually align the Gemini docking bar with the Agena. As a basis for selecting appropriate control actions he must assess the magnitude, velocity and acceleration (if any) of the alignment error.

Factor 2: Movement Prediction

Definition. - This is the ability to take information from higher order (velocity, acceleration) systems and to predict position through time on the basis of this information.

Related Space Performance. - When an astronaut uses the Gemini attitude control loop, he operates upon attitude velocity and acceleration. To achieve a change in a particular attitudinal axis, he must first impart an acceleration and then a deceleration so that motion will cease as the desired attitude is reached. Thus he estimates, or predicts, the final attitude as the time integral of the velocity and acceleration component of motion.

Factor 3: Rate Control

Definition. - This is the ability to control a dynamic system in which system velocity is directly proportional to the force applied to the control.

Related Space Performance. - The Gemini is equipped with a three axis (pitch, roll, yaw) rate control and a digital incremental velocity indicator for each axis. When velocity changes are required, they appear on the display. The astronaut then operates his rate control to drive the displayed values to zero.

Factor 4: Acceleration Control

Definition. - This is the ability to control a dynamic system in which system acceleration is directly proportional to the force applied to the control.

Related Space Peformance.- In a weightless (zero-g) environment the use of thrusters to effect changes in system velocity and attitude constitutes a second order system. The vehicle will be accelerated in proportion to the magnitude of force supplied by the thrusters. In several modes of operation of the Gemini and the coupled Gemini - Agena system, the force thus applied is directly proportional to the magnitude and/or duration of control deflection.

Category IV: Perceptual-Cognitive Abilities

Factor 1: Perceptual Speed

Definition.- This is the ability to make rapid comparisons of visual detail.

Related Space Performance.- The constant monitoring and verifying required throughout a Gemini mission will require perceptual speed. During Rendezvous, the limitations placed upon fuel expenditure and the nature of Rendezvous require the Flight Director Reference, Incremental Velocity Indicator, Range/Range Rate Indicators and propellant quantity to be constantly monitored during translation and attitude maneuvers.

Factor 2: Time Sharing

Definition.- This is the ability to obtain and utilize information presented within more than a single visual display. There is information (Riggs and Howell, 1959; and Parker, 1964) which indicates that when an operator is located approximately thirty inches from his console, instruments must be separated by more than sixteen inches before this ability becomes important.

Related Space Performance.- Gemini astronauts will be required to monitor dials, displays, warning lights, and circuit breaker positions from the time of entry into the capsule until successful completion of the mission. Checking switch positions and circuit breakers on the left and overhead switch/circuit breaker panels; dials, displays and gauges on the Command Astronaut's panel; sequence and warning lights, and switches on the center panel and pedestal, will require extensive time sharing. Time sharing will be particularly important during periods of manual control (Rendezvous), and rigorous temporal sequencing (Retrograde and Re-entry).

Category V: Reaction Time Ability

Factor 1: Reaction Time

Definition.- This ability involves the speed with which a person can react to a stimulus when it appears.

Related Space Performance.- During the Docking phase of Rendezvous, the astronaut will be required to dock with the Agena target vehicle using only visual references. The small docking tolerances will require fast reactions in controlling attitude and translation. Quick reactions will also be critical during Retrograde, Re-entry and Landing.

Category VI: Mirror Tracing Ability

This ability is unique in the sense that it is the only factor which is not supported on the basis of the search of the technical literature. However, consideration of the tasks to be required of Gemini personnel clearly indicates that an ability such as this may be required. An attempt to include a test of this ability within the prototype battery appears warranted.

Factor 1: Mirror Tracing

Definition.- This is the ability to perform manipulative actions while using visual feedback from a mirror-image display.

Related Space Performance.- The Gemini capsule is equipped with mirrors which permit an astronaut to see all areas of the capsule outside of his direct field of view. A number of manipulative actions will be accomplished by use of these mirrors.

Table 1 summarizes the above ability factors and associated space activities.

# TABLE 1: SUMMARY OF SELECTED ABILITY FACTORS

| Ability Factor | Description of Behavior | Adequacy of Identification | Associated Space Activity |
|---|---|---|---|
| Fine Manipulative Abilities | | | |
| Arm - Hand Steadiness | Hold arm and hand steady while fully extended. | High loadings in several studies | Use utility pole to reach switches. |
| Wrist - Finger Speed | Make rapid, repetitive tapping movements | High loadings in several studies | Perform general keyboard operations. |
| Finger Dexterity | Manipulate small objects with fingers. | High loadings in several studies | Manipulate switches. |
| Manual Dexterity | Manipulate large objects with hand. | Varied loadings in several studies | Use larger control handles. |
| Gross Positioning and Movement Abilities | | | |
| Position Estimation | Reach for specific locations without use of vision. | Low loadings on single study | Grasp peripheral control switches. |
| Response Orientation | Make appropriate directional response to non-spatial stimulus. | Varied loadings in several studies | Use digital displays in vehicular control. |
| Control Precision | Make fine, controlled positioning movements. | Varied loadings in several studies | Use attitude and maneuver controls. |
| Speed of Arm Movement | Make discrete, rapid arm movements. | Varied loadings in several studies | Perform rapid sequence of control settings. |
| Multilimb Coordination | Use hands and/or feet simultaneously. | Varied loadings in several studies | Use attitude and maneuver controls. |
| Position Reproduction | Repeat discrete arm-hand movement without aid of vision | Low loadings on single study | Intermittent use of peripheral controls. |

## TABLE 1: SUMMARY OF SELECTED ABILITY FACTORS

| Ability Factor | Description of Behavior | Adequacy of Identification | Associated Space Activity |
|---|---|---|---|
| System Equalization Abilities | | | |
| Movement Analysis | Differentiate traget velocity and acceleration. | High loadings in single study | Perform rendezvous maneuvers in visual mode. |
| Movement Prediction | Integrate target motion components to estimate future target position. | Low loadings in single study | Perform rendezvous maneuvers in visual mode. |
| Rate Control | Control vehicle having first order system dynamics. | Varied loadings in several studies | Operate attitude and maneuver subsystems. |
| Acceleration Control | Control vehicle having second order dynamics. | Varied loadings in several studies | Operate attitude and maneuver subsystems. |
| Perceptual-Cognitive Abilities | | | |
| Perceptual Speed | Make rapid visual comparisons of display elements. | Low loadings in several studies | Scan complex system displays. |
| Time Sharing | Divide attention among several displays. | High loadings in single study | Monitor control panel. |
| Reaction Time Ability | | | |
| Reaction Time | Respond as rapidly as possibly to discrete signal. | High loadings in several studies | Make control responses where time is critical. |
| Mirror Tracing Ability | | | |
| Mirror Tracing | Use mirror-image display to perform directional hand-arm movements. | Not identified in factor analytic studies | Use panel mirrors to locate and operate peripheral controls. |

## CONFIGURATION OF PROTOTYPE TESTS

Each factor accepted for study has had associated with it, on the basis of previous investigations, one or more tests designed to measure that particular ability. These previously-used tests were examined with respect to four criteria in the belief that some modified version of the test might be appropriate for inclusion in the test console under development. The four criteria are:

1. Is the test minimal in terms of size and weight and number of components?

2. Can the test be easily self-administered and automatically scored?

3. Will the test in its present form function under conditions of weightlessness?

4. Can the test be incorporated into a unified test console?

With the exception of a very few factors, the four criteria were not met completely. Consequently, most of the tests in the prototype battery are completely new or represent modifications of relatively standard perceptual-motor tests.

The following paragraphs describe the basic configuration of each test:

### Category I: Fine Manipulative Abilities

#### Factor: Arm-Hand Steadiness

Considerations in Test Development.- No significant modifications were required to incorporate this standard test (Fleishman, 1954, 1958a, 1958b)[1] into the battery for use under zero-g conditions.

Test Configuration.- This device tests the subject's ability to maintain his hand and arm in a steady state while fully extended. The apparatus

[1]References cited in this section relating to standard tests are listed at the end of Appendix A.

consists of a stylus and a panel with a 3/16" aperture. The subject is required, upon signal, to extend his arm, insert the stylus into the hole, and maintain it there without touching the circumference of the opening. The number of contacts accumulated over three 10-second trials is the dependent measure.

Factor: Wrist-Finger Speed

Considerations in Test Development. - Tests of this ability (Fleishman, 1954; Fleishman and Ellison, 1962) require rapid, repetitive, jabbing movements of the fingers when aiming is not critical. Usually the test consists of a printed form, and the subjects tap back and forth between two large circles for a specified amount of time. Performance is measured by counting the number of dots produced within the circles. To eliminate the use of paper and pencil, two keys were substituted upon which the subject would tap alternately as rapidly as possible, with the taps being counted automatically.

Test Configuration. -Two flush-mounted switches 1-1/8" long by 3/4" wide are located two inches apart directly in front of the subject. These provide the contact surfaces for tapping. When a signal light appears, the subject begins tapping as rapidly as possible, alternating between the two keys using the index finger of his preferred hand. A programming device registers the number of taps on a counter for a 10-second interval. At the end of this period the signal light is extinguished, signifying the end of the trial. At the same time, the counter is disconnected to prevent recording of any tap made beyond the 10-second interval. Test score is the total contacts accumulated over three 10-second trials.

Factor: Finger Dexterity

Considerations in Test Development. -The use of standard test, Purdue Pegboard, and Purdue Pegboard-Assembly (Fleishman and Ellison, 1962), requires sets of small objects. This was considered undesirable in a weightless environment in which objects may tend to float around and thus interfere with efficient test administration. As with the test of manual dexterity, this test was redesigned to have a minimum of components while retaining the basic test features.

Test Configuration . -This test requires the manipulation, assembly, and disassembly of small objects, using the fingers of both hands. The test consists of a panel having three columns of tapped holes. The holes are of two sizes, whichare alternated within each column. Each size corresponds to a shape-coded threaded unit. The larger holes receive a unit with a square body; the smaller holes receive a unit with a hexagonal body. The

shape of the unit received (square or hex) is etched around each hole to facilitate location during test performance. The two units are joined by means of a threaded stud on the square unit and a tapped hole on the hex unit.

At the start of the test, the subject takes a unit in each hand and joins these units together as he would with a standard nut and bolt. He then screws the assembly into the bottom hole (hex) of the center column. The subject then retrieves the unit, disassembles it, and screws each part into its corresponding hole in the right-and left-hand columns. The units are again retrieved, assembled, and screwed to the next hole in the center column. This procedure is repeated until the assembled unit is placed into the top hole (hex) of the center column. Time for completion of the sequence is the dependent measure.

Factor: Manual Dexterity

Considerations in Test Development.- The present test is the same in principle as the standard test of manual dexterity, the Minnesota Rate of Manipulation-Turning (Bourassa and Guion, 1959). The use of a single object to be manipulated rather than a set of different objects, however, represents a major departure from standard techniques. This innovation was dictated by the requirements for use in a weightless environment. Under weightless conditions, objects are likely to float away from the subject and present administrative difficulties. The present alternative requires no special anchoring techniques such as the use of magnets, etc., which might actually tend to interfere with task performance. In addition to overall simplicity, the use of a single test object is economical in terms of size and weight.

Test Configuration.- The apparatus consists of a panel containing six receptacles of varying size, shape, and color and a solid "key" having projections that correspond to the various panel openings. The subject's task is to manipulate the object with one hand, align and insert each projection into its proper receptacle, moving clockwise around the panel. Time to traverse twice around the panel is the dependent measure.

## Category II: Gross Positioning and Movement Abilities

Factor: Position Estimation

Considerations in Test Development.- Standard test procedures (Fleishman, 1958) were retained in the development of this test. The apparatus

was modified to permit automatic programming, scoring, and integration into the test console.

Test Configuration.- A row of three, 3-ring targets is located approximately 30 inches in front of the subject and 10 inches above eye level. The subject's task is to contact a designated target with a stylus according to the following procedure. The subject, seated at the test console, grasps the stylus and places it on a starting point located four inches in front of him on the lower section of the console. This point displays an arrow indicating which target is used on a particular trial. Without moving his hand, he visually locates the target, then returns his gaze to the starting point and remains fixated on that position. Then, without looking, he attempts to contact the center of the target with the stylus. Accuracy is stressed. Speed is not relevant. A bull's-eye is scored 3 points; next ring, 2 points; and the outer ring is one point. The score is displayed automatically on the console. Test score is the mean of 10 trials over a random target sequence.

Factor: Response Orientation

Considerations in Test Development.- The emphasis of this test is on a subject's ability to produce a discrete directional response to a nonspatial (nondirectional) stimulus. This situation is analogous to one in which binary (go, no-go) or digital displays are used in a vehicle, and contrasts with displays such as the gyro-horizon, compass, altimeter, etc., which provide directional information in spatial form. The present test was developed following the procedures used in the Choice Reaction Time Test (Parker and Fleishman, 1960) and Complex Multiple Reaction Test (Fleishman and Hempel, 1954). Responses were limited to a single hand rather than requiring use of all four limbs as in the standard tests.

Test Configuration.- This test requires the subject to make a control switch deflection in one of four directions in response to a discrete, nonspatial signal.

A 1-1/2" by 3/4" translucent display unit, in a fixed location (center of console), is illuminated as one of four colors: red, white, yellow, or green. Each color requires a specific control movement: left, right, forward, or back. Total time to make the correct responses to a predetermined sequence of 24 stimulus events is the test score.

Factor: Control Precision

Considerations in Test Development. - The Rotory Pursuit Test (Fleishman, 1957) and Rudder Control Test (Fleishman, 1954) normally used to measure this ability were unacceptable in terms of size and weight. In addition, the Rudder Control Test requires the force of gravity in order to function. The test was redesigned as an electronic rotary pursuit task in the form of a pursuit control system with a circular target course.

Test Configuration. - The apparatus consists of a two-dimensional cathode ray tube display and a two-axis control stick. As a target dot travels in a circular path on the CRT, the subject attempts to keep a second marker dot superimposed on the target by moving the control stick through a circular path. Integrated error between target and follower is the dependent measure of performance. Error measures are obtained separately for the vertical and horizontal axes.

Factor: Speed of Arm Movement

Considerations in Test Development. - The Rate of Movement (Fleishman, 1957a) and Ten Target Aiming (Fleishman, 1954) tests were considered to be too complex in terms of apparatus, administration, and scoring for present purposes. A simpler task requiring a rapid, discrete arm movement between two points was designed as an alternate method of measuring this ability.

Test Configuration. - Two switches are located 24 inches apart from left to right, 12 inches in front of the subject. The subject's task is to place his hand above the left-hand switch and at his discretion strike this switch and then move his arm horizontally as rapidly as possible to strike the second (right-hand) switch. A timer starts as the first switch is touched and stops when the second is struck. Speed of arm movement is derived from the time required to traverse the distance between switches.

Factor: Multilimb Coordination

Considerations in Test Development. - The standard Rudder Control Test (Fleishman, 1954) from which this factor was derived requires the use of specially designed seat and foot controls. A two-hand coordination task and a CRT display were substituted for the above apparatus on the assumption that these tasks would be closely related.

Test Configuration. - The test is a two-axis compensatory tracking task with a separate control for each axis of target movement. The left hand

controls the vertical (y) axis while the right hand controls the horizontal (x) axis. Rate control dynamics are used in this task. A sinusoidal forcing function is used to drive the target off center. The subject is required to keep the target dot centered by coordinating left- and right-hand control movements. The dependent measure is integrated tracking error obtained separately for each axis.

Factor: Position Reproduction

Considerations in Test Development. - Four tests (Fleishman, 1958a) have been found to measure this ability. Common to all of these tests is the requirement that the subject make a discrete hand-arm movement between a starting point and a designated location. He then returns his hand to the starting point and attempts to reproduce the original movement. He is not allowed the use of vision at any point in this test. The initial movement customarily is guided by an experimenter. A performance score is obtained by accumulating the location error over a series of trials.

It was felt that the apparatus designed for the Position Estimation Test (Fleishman, 1958a) could be used appropriately in the measurement of position reproduction. However, since all tests in the present battery are designed for self-administration, an alternative procedure to the standard was required. Specifically, the initial response had to be made without the aid of an experimenter. It was decided that permitting the subject to make this response while viewing the display, and then having him repeat the movement while viewing a designated point, would not contaminate the test results.

Test Configuration. - The apparatus is that described under Position Estimation. In the present test, a target is designated. The subject moves his stylus to the target and back to the starting point as he views the target. He visually fixates on the starting point and attempts to contact the target again by reproducing his initial movement. Depending upon which of the three target rings is contacted, the subject receives a score of one, two, or three points, which registers automatically on a panel display unit.

## Category III: System Equalization Abilities

Factor: Movement Analysis

Considerations in Test Development. - With the exception of minor changes in procedure, the best measure of this ability, Electronic Single Differentiation Test (Parker, 1964), has been incorporated directly into the test battery.

Test Configuration. - In this test, a target dot moves in the horizontal axis across the face of the CRT. The subject views the dot and judges whether it is moving at constant velocity, accelerating, or decelerating. His task is to reduce the acceleration component of motion to zero (adjust to constant velocity) by use of a rotary control knob having no positional cues. Each time the dot sweeps across the display, the subject makes an acceleration control adjustment, resets the computer, and again views the dot in motion. This procedure is repeated until the subject is satisfied that the dot is moving at a constant velocity. Five acceleration conditions are used and are selected for presentation in a predetermined sequence.

It is assumed that this test measures the ability of the subject to detect the acceleration component of motion and to remove it. He then must verify that the motion characteristic of the final dot traverse is pure velocity. The magnitude of the acceleration component (deviation from constant velocity) remaining is the measure of performance.

Factor: Movement Prediction

Considerations in Test Development. - The original test (Parker, 1964) from which this factor was derived used a ball rolling down an inclined plane. The subject was required to predict the time at which the ball reached a given point after being occluded from view. Clearly, this gravity-operated device would not be appropriate under conditions of weightlessness. Two alternative test methods, a linear electronic display and a rotary electromechanical display, were considered as possible alternatives.

As a result of preliminary experimentation, it was decided that a CRT display which presented a target dot moving in the horizontal axis would provide an adequate range of angular velocities for measurement of this ability. This context also appeared to be a more direct transposition of the original test than would be a rotary display.

Test Configuration. – In this test, the subject selects each of five predetermined target velocities by means of a selector switch. Target motion across the face of the CRT display is initiated by pressing a key. When the dot reaches the center of the display, it disappears. The subject continues

to depress his response key until he judges that the dot has arrived at the furthermost scale line on the right side of the display. At this time he releases his key, causing the dot to reappear and hold. Performance is scored as deviation from the scale reference line.

Factor: Rate Control

Considerations in Test Development.- The original test from which this factor was derived (Parker, 1964) utilized a similar electromechanical tracking situation. Only system gains and course characteristics have been changed to provide the present test with an appropriate level of difficulty.

Test Configuration.- The subject is required to perform a two-dimensional tracking task with a first-order (rate) control system. In this system, out-put (target) velocity is proportional to the magnitude of control displacement. He attempts to keep a target dot centered on the face of a CRT display by manipulating a control stick in two dimensions. A sinusoidal forcing function provides the tracking course. Integrated error voltage is recorded as the measure of tracking performance.

Factor: Acceleration Control

Considerations in Test Development.- As with Rate Control, the basic electromechanical configuration of the test as originally used (Parker, 1964) is retained in the present test. System gains and course characteristics have been set to provide an appropriate level of difficulty.

Test Configuration.- The subject is required to perform a two-dimensional compensatory tracking task with a second-order (acceleration) system. In this system, target acceleration is proportional to control stick displacement. The task is to maintain the target dot in the center of a CRT display by manipulating a control stick in two dimensions. A tracking course is provided by a sinusoidal forcing function. Integrated error voltage is recorded as the measure of performance.

## Category IV: Perceptual-Cognitive Abilities

Factor: Perceptual Speed

Considerations in Test Development.- Perceptual Speed as defined in the factor-analytic literature represents a rather complex skill in terms of operational measurement. It appears to fall within the domains of both

time-sharing and vigilance, areas which have as yet not been clearly delineated with respect to critical variables. At the very least, performance will vary with the number and complexity of displays used, their location, the magnitude of deviation displayed, the duration of viewing required, and the scanning strategy employed by the subject.

Two standard tests, Speed of Identification (Fleishman, 1957b) and Visual Pursuit (Fleishman, 1957a) have been used to measure perceptual speed. These are both printed (paper and pencil) tests. Tests of this form were considered inappropriate with respect to the desired end product of an integrated console. For this reason, meters are used in the present test to replace the printed stimulus material and the subject uses switches to report his detections.

Test Configuration.- This test is designed to measure the subject's ability to scan a complex display and make a rapid assessment of system status. Specifically, the subject is presented with a series of indications on two meters. His task is to determine as rapidly as possible whether the two indications are the same or different and respond by pressing a key appropriate to each category. If the response is correct, the next pair of indications appears. If the response is incorrect, an error is registered on a counter. The dependent measures are time to complete a series of 24 presentations and number of errors made in responding.

Factor: Time Sharing

Considerations in Test Development.- Time sharing customarily is measured (Parker, 1964) by presenting the subject with two or more displays which cannot be attended to simultaneously. The subject's task is to scan or divide his attention among these displays in an attempt to detect deviations from a standard condition. In some instances the displays may be part of a control system and would be affected by the subject's action.

Test Configuration.- The subject is required to scan back and forth between two meters located on either side of the console front. The meters are placed so as to prevent simultaneous viewing by maintaining an intermediate point of fixation. At predetermined irregular intervals, a meter will begin to move. The subject's task is to detect the onset of movement as rapidly as possible and respond by pressing a key corresponding to that meter. A timer runs whenever a meter is moving. Detection times for 24 events are cumulated over a four-minute time-sharing test period.

## Category V: Reaction Time Ability

Factor: Reaction Time

Considerations in Test Development.- Reaction time is defined as the duration between the onset of a stimulus and the occurrence of a response. The use of a sound as the stimulus defines Auditory Reaction Time (Fleishman, 1958b). Use of a light stimulus defines Visual Reaction Time (Fleishman, 1958b). The response in the majority of simple reaction time tests is finger withdrawal from a spring-loaded response key. These standard procedures were incorporated with a single minor modification: the present test requires the subject to press a switch rather than withdraw his hand from it. Both auditory and visual reaction time measures are obtained.

Test Configuration.- For the Visual Reaction Time Test the subject observes a stimulus lamp while holding the first digit of his preferred hand slightly above the surface of his response key. When the lamp is illuminated, the subject presses the key as rapidly as possible. A timer is activated when the light goes on and stops when the response key is pressed. Reaction time is recorded directly from the timer.

For the Auditory Reaction Time Test the procedure and response are identical to those for Visual Reaction Time except that a tone is used as a stimulus in place of the light.

## Category VI: Mirror Tracing Ability

Factor: Mirror Tracing

Considerations in Test Development.- In previous space flights, astronauts have used mirrors attached to their wrists for viewing overhead control panels. The Gemini control panel is equipped with mirrors for this purpose. In addition, maintenance men frequently use a mirror to view recessed areas in equipment in the process of making adjustments and repairs. In view of these facts, the inclusion of a task requiring eye-hand coordination with the use of a mirror seems to be justified.

Test Configuration.- This test requires the subject to make a sequence of hand-arm movements based upon visual information which is inverted from front to back. The subject is asked to trace a complex pattern (maze) with a stylus while viewing the pattern and his hand in a mirror. The pattern is of

nonconductive material surrounded by metal. Whenever the stylus touches the metal, an error is registered on a counter. Dependent measures are total contacts and time to complete the maze.

## DESCRIPTION OF TEST CONSOLE

The completed test console is shown in Figure 1. All electronic and electro-mechanical components are contained within this unit. Controls required for test set-up and performance are within reach of the seated operator. The manual dexterity test elements are shown in place on the lower panel as they would be during testing of this ability. These items are removable so that the same location can be used for the finger dexterity and mirror tracing templates.

Integral lighting of the microswitch units is coordinated with the selector switches such that appropriate control units are illuminated as each task is selected. In some instances, lights serve as stimuli as well as for the alpha-numeric display of scorer and system status.

Figure 2 includes the console base which stores accessory equipment. It has two press-to-open cabinet doors on its front. Also shown is the clock shield which swings over to mask the clock during certain tests. Not shown in the figures are the three targets which project above the top of the console from their receptacles on the back.

Additional test items and accessories are shown in Figure 3. Included are the mirror-tracing goggles, manual dexterity test, scope hood (for fixed CRT viewing distance), finger dexterity test, stylus and mirror tracing maze.

A complete description of the console interface and operating instructions is presented as Appendix C.

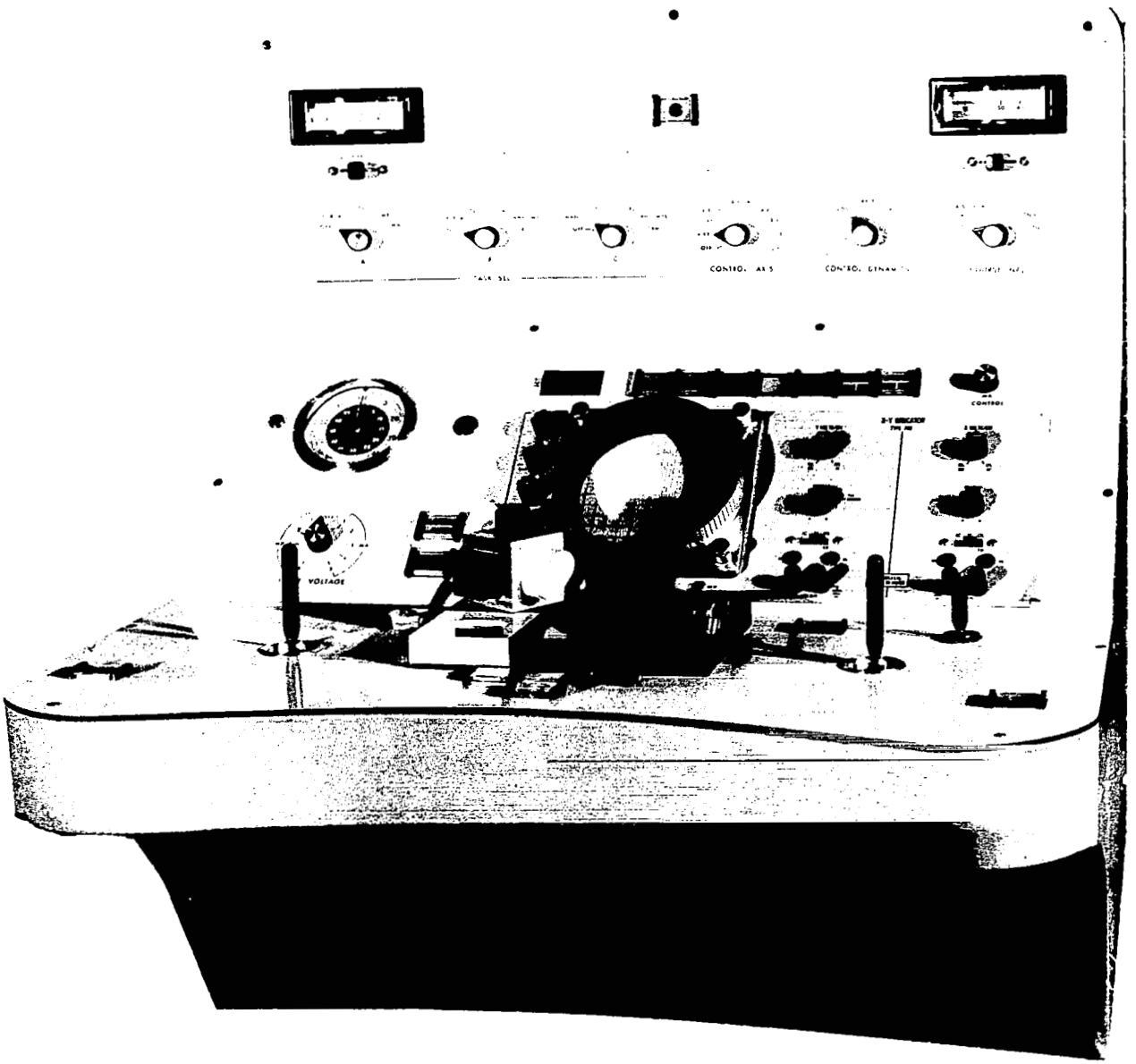


Figure 1. Perceptual-Motor Performance Measurement Console.

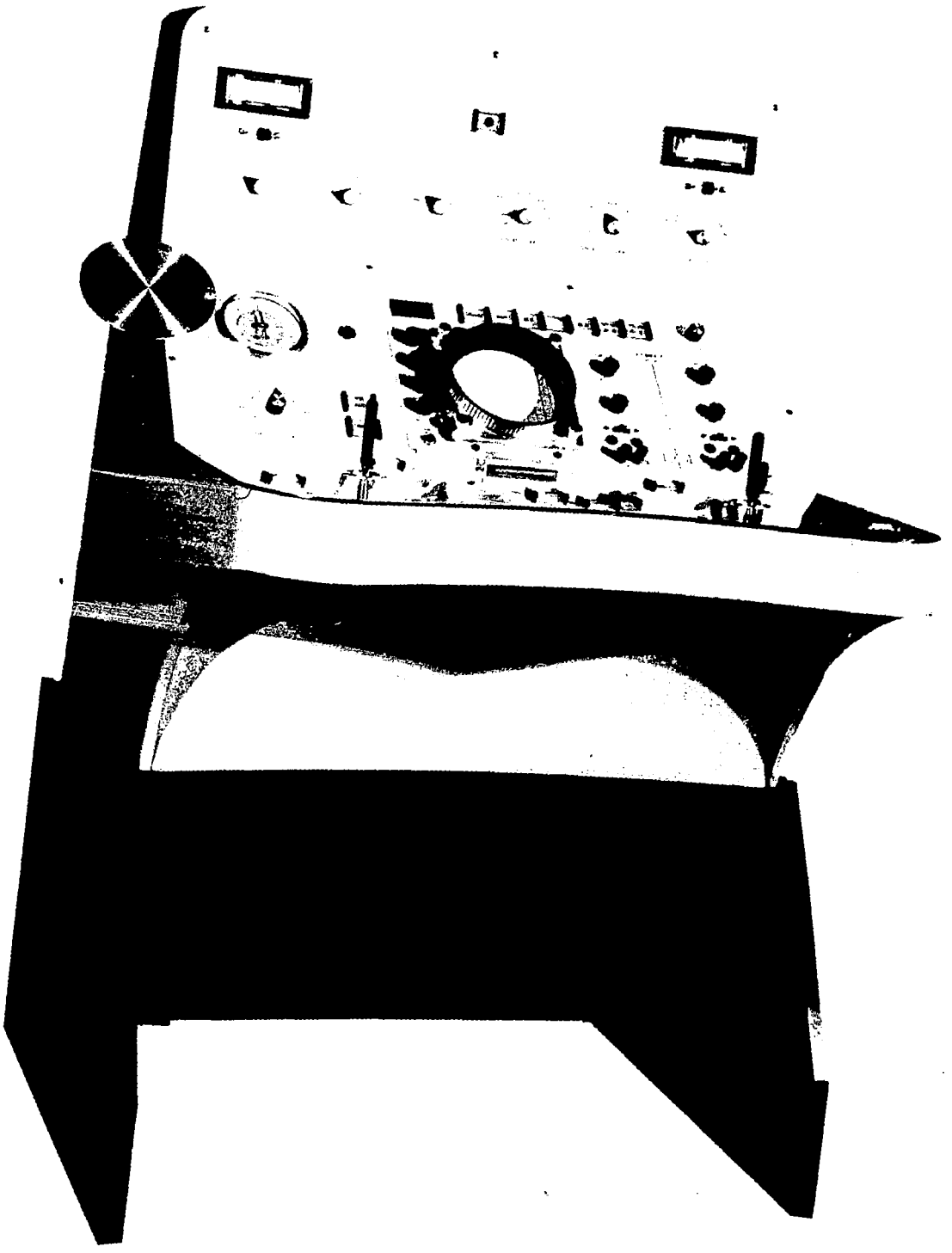

Figure 2. Measurement Console and Base.

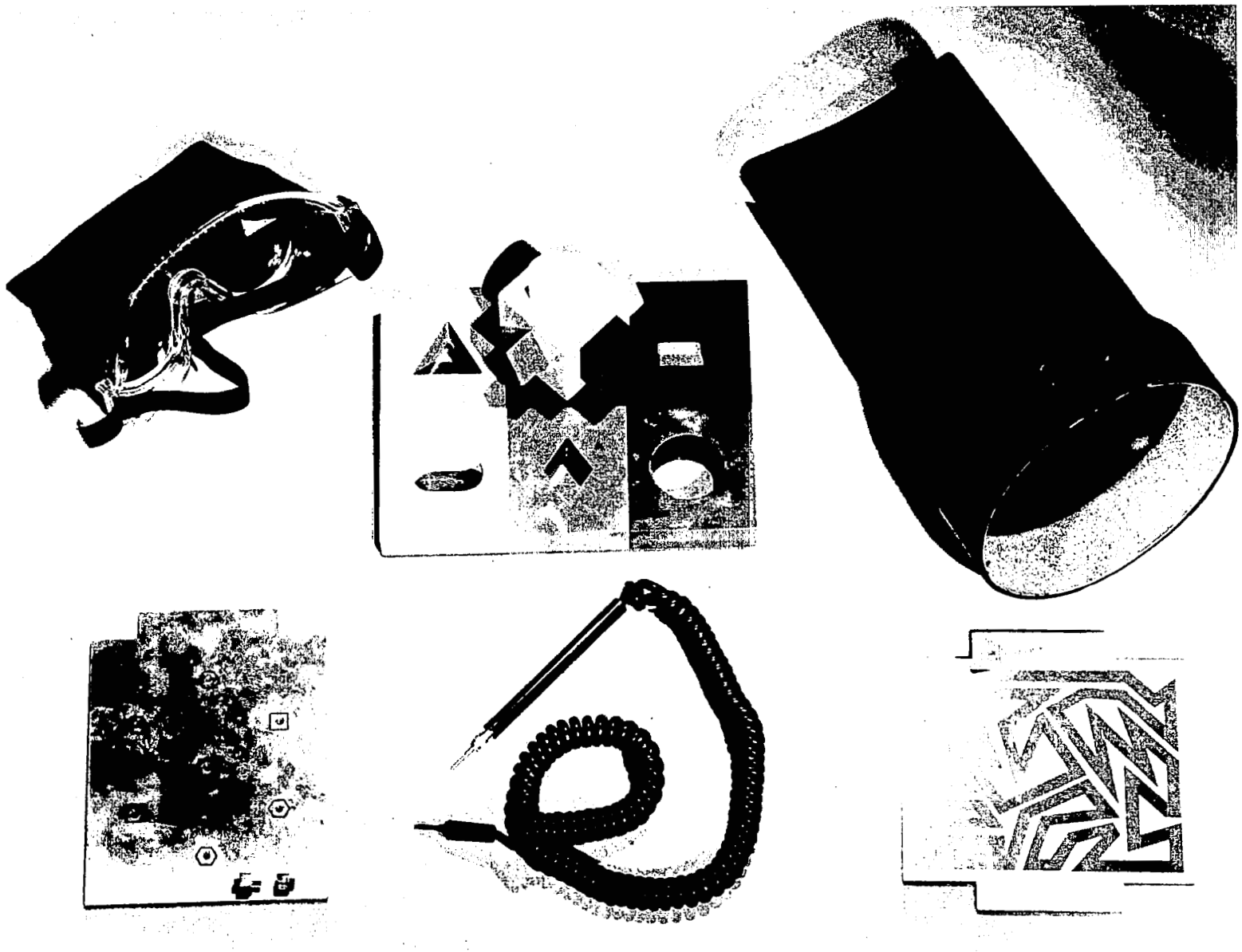

Figure 3. Test Items and Accessories Used with Console.

## PRELIMINARY TEST RESULTS

Ten healthy male subjects were tested on each of the eighteen abilities. The purpose was to obtain estimates of mean performance scores and the variability associated with these scores. In addition, this effort permitted the refinement of test procedures and instructions and provided an estimate of administration time for each test. The results are presented in Table 2 which includes the mean and standard deviation for each test, based on the ten subjects, and the approximate time required to instruct and administer each item to subjects unfamiliar with the console and procedures. Completion of all eighteen tests required approximately two hours. However, based on observation of other individuals who were familiar with the console, it appears that given adequate indoctrination, overall testing time may be substantially reduced.

During preliminary testing, subjects exhibited wide individual differences on all tasks. Practice was held to a minimum determined by two criteria:

(1) the subject should understand the test procedure and control-display relationships sufficiently well to insure completion of each trial;

(2) performance should be within the limits of the scoring mechanisms (as in tracking) or reasonably consistent with expected scores based on the literature (as in reaction time).

In general, one or two trials were sufficient to achieve scorable performance on abilities not concerned with tracking. Of the tracking tests, Multilimb Coordination and Acceleration Control required the greatest amount of practice before a subject could maintain system control. As a rule, five to ten minutes of continuous practice on the tasks were enough to permit scoring. In three instances it was necessary to allow practice in each axis separately before the subjects could learn the control-display relationships and equalize the system dynamics.

TABLE 2

SUMMARY OF PRELIMINARY TEST PERFORMANCE SCORES

| Test | Mean Score | Stan. Dev. | Basis | Admin. Time Including Setup |
|---|---|---|---|---|
| Fine Manipulative Abil's | | | | |
| Arm-Hand Steadiness | 56 contacts | 10.9 | Sum of three 10-sec. periods | 2 min. |
| Wrist-Finger Speed | 149 contacts | 11.5 | Sum of three 10-sec. periods | 2 min. |
| Finger Dexterity | 88 seconds | 37 | Time to complete one board sequence | 4 min. |
| Manual Dexterity | 53 seconds | 11.1 | Time to go twice around board | 3 min. |
| Gross Positioning and Movement Abilities | | | | |
| Position Estimation | 15 points | 3.1 | Total for ten targets | 3 min. |
| Response Orientation | 15 seconds | 2.4 | Cumulated response time for 24 stimulus presentations | 4 min. |
| Control Precision | 18 (y axis)<br>17 (x axis) | 9.1<br>8.7 | Tracking error over last 56 seconds of one-minute trial | 4-8 min. |
| Speed of Arm Movement | .29 seconds | .031 | | 2 min. |
| Multilimb Coordination | 33 (y axis)<br>28 (x axis) | 10.9<br>9.0 | | 5-10 min. |
| Position Reproduction | 16 points | 3.0 | Total for ten targets | 3 min. |

(continued)

TABLE 2--Continued

SUMMARY OF PRELIMINARY TEST PERFORMANCE SCORES

| Test | Mean Score | Stan. Dev. | Basis | Admin. Time Including Setup |
|---|---|---|---|---|
| System Equalization Abilities | | | | |
| Movement Analysis #1<br>#2<br>#3<br>#4<br>#5 | 1.0 (absolute<br>0.6 scale ad-<br>0.4 justment<br>0.5 error)<br>0.6 | ----- | Unlimited adjustments allowed | 10 min. |
| Movement Prediction at Angular Velocity | | | | |
| #1 .0195 (rad/sec)<br>#2 .0369<br>#3 .0553<br>#4 .0830<br>#5 .3688 | .0226 (mean ab-<br>.0144 solute<br>.0175 error/<br>.0226 radians)<br>.0257 | ----- | One trial per velocity setting | 4 min. |
| Rate Control | 16 (y axis)<br>17 (x axis) | 3.1<br>6.1 | Tracking error over last 56 seconds of one-minute trials | 5-10 min. |
| Acceleration Control | 25 (y axis)<br>35 (x axis) | 6.9<br>8.1 | See Rate Control above | 5-10 min. |

(continued)

TABLE 2--Continued

SUMMARY OF PRELIMINARY TEST PERFORMANCE SCORES

| Test | Mean Score | Stan. Dev. | Basis | Admin. Time Including Setup |
|---|---|---|---|---|
| Perceptual-Cognitive Abilities | | | | |
| Perceptual Speed | 61 seconds<br>2.4 errors | 12.6<br>1.5 | Time to complete one sequence. | 3 min. |
| Time Sharing | 30 seconds | 5.4 | Cumulative response (detection) time for 24 events | 7 min. |
| Reaction Time Ability | | | | |
| Visual | .23 seconds | .031 | ---------- | 4 min. |
| Auditory | .22 seconds | .050 | ---------- | |
| Mirror Tracing Ability | | | | |
| Mirror Tracing | 76 seconds | 19 | Distribution is bimodal | 3-6 min. |

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Note: A complete listing of those studies used in the selection of tests for inclusion in the test console is presented at the end of Appendix A.

# APPENDIX A

## SUMMARY OF ABILITY FACTORS

Appendix A is a comprehensive listing of ability dimensions which have been isolated through factor-analytic investigations of perceptual-motor performance. All of the information necessary to make an objective evaluation of a factor is contained in this appendix. First, the factor is defined. In most cases the definition comes from one of the studies which identified the factor. In some cases, where the meaning of a factor evolved through succeeding studies, the definition shown is a composite of a number of different definitions.

The first column in the table describing a factor lists tests which have been found to have loadings on this factor, the specific loadings, and references for the studies which identified the factor. While descriptions of identifying tests are not included in the table, descriptions are available in one or more of the indicated references. The first number within a set of parentheses refers to the loading of a test on the factor. When a study included more than one score for a test, the scores usually represented early and late performance. In such cases the loading for the score taken at the latest stage of performance is included in the table. The second number within a set of parentheses refers to the list of references at the end of Appendix A. Table 3 presents excerpts from the factor Manual Dexterity to illustrate the information presented within each table. The first entry in the first column indicates that Reference 1 found the Pin Moving Test to have a loading of .32 on the Manual Dexterity factor.

When evaluating a factor or an identifying test, one of the most relevant questions that can be asked is, "In different investigations, how consistently has this test had the same loading on this factor?" In general, a loading of .30 or higher can be considered significant. If a test had a loading above .30 on a factor in one study, and the same test had a loading below .30 on the same factor in another study, the appropriateness of this test for identifying the factor might be questioned. In order to include the information necessary for an evaluation of this factorial invariance, the following procedure was used. If a test loaded above .30 on a factor in any study, a loading was included for all studies which contained that test and found the factor. The single entry (.32, 1) for the Pin Moving Test means that Reference 1 was the only study which included the Pin Moving Test and also found a Manual Dexterity factor. Note also that the second entry, Rotary Pursuit, indicates that this test was used in three studies which found a Manual Dexterity factor. This, of course, does not mean that the studies cited in Column One are the only studies which included this test within the battery of reference, or predictor, tests.

TABLE 3

ILLUSTRATION OF INFORMATION PRESENTED IN THE TABLE DESCRIBING EACH ABILITY FACTOR.

FACTOR: Manual Dexterity

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Pin Moving | (.32,1) | Visual Feedback | (.31,1) |
| Rotary Pursuit | (.17,2)(.35,11)(-.06,18) | Control Precision | (.26,3)(.49,7)(.60,18) |
| | | Speed of Arm Movement | (.22,2)(.47,3)(.17,6)(.20,7)(.34,10)(-.02,18) |

The second column presents information with which to evaluate the "purity" of a test. A test is considered pure if it loads only on one factor. In the second column are listed all other factors on which the identifying test in the first column loads. In our example, Reference 1 showed the Pin Moving Test to have loadings of .32 on the Manual Dexterity factor and .31 on the Visual Feedback factor. These were the only factors on which the Pin Moving Test had a significant loading.

Factorial invariance is as much a concern for "other" factors as it is for the factor under consideration. For this reason, loadings are included for "other" factors in the second column for all studies which found the factor and contained the identifying test. Again, for the test to be included it must have loaded as high as, or higher than .30 on the "other" factor. The combination of the first and second columns lists all studies which included the test, and all factors on which the test loaded.

FACTOR: Ability to Deal with Linear Extents (Tentative)

Defined as : the ability to perceive the length of a line and then to manipulate that length in some manner.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors |
|---|---|---|
| Analog Addition (Printed) | (.57, 17) | |
| Multiplication by a Constant (Printed) | (.60, 17) | |

FACTOR: Ability to Deal with Rotational Magnitudes (Tentative)

Defined as : the ability to view a rotating wheel and to make some judgment concerning the magnitude of rotation.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors |
|---|---|---|
| Analog Addition (Mechanical) | (.33, 17) | |
| Multiplication by a Constant (Mechanical) | (.45, 17) | |

FACTOR: Aiming

Defined as : the ability to perform quickly and precisely a series of movements requiring eye-hand coordination. This definition seems much too broad, since many other kinds of psychomotor tests require eye-hand coordination. This factor is best measured by printed tests.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Aiming | (.63,2)(.36,7)(.57,9) | Finger Dexterity | (.12,2)(.35,7)(.30,9) |
| | | Wrist-Finger Speed | (.45,2)(.52,9) |
| Circle Dotting | (.69,15) | | |
| Cox Pin Board | (.31,15) | | |
| Irregular Dotting Pursuit (Printed) | (.82,15) | | |
| Marking Accuracy | (.37,2)(.40,7) | Spatial Orientation | (.35,10)(.34,18) |
| Minnesota Rate of Manipulation (Placing) | (.34,9) | Finger Dexterity | (.31,2)(.37,9)(.36,18) |
| | | Manual Dexterity | (.73,1)(.32,2)(.53,9) (.38,18) |
| | | Speed of Arm Movement | (.36,2)(.24,9)(-.13,18) |
| Pattern Discrimination (Printed) | (.36,15) | | |
| Pursuit Aiming I (3/16 diam.) | (.68,2)(.63,9) | Wrist-Finger Speed | (.50,2)(.52,9) |

FACTOR: Aiming

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Pursuit Aiming II (1/8 diam.) | (.63,2)(.63,9) | Wrist-Finger Speed | (.48,2)(.54,9) |
| Rotary Aiming | (.22,9)(.38,15) | Speed of Arm Movement | (.46,2)(.38,6)(.53,7)(.02,18) |
| | | Wrist-Finger Speed | (.36,2) |
| Santa Ana Finger Dexterity | (.17,7)(.33,15) | Finger Dexterity | (.16,2)(.42,7)(.46,12)(.06,15) |
| | | Manual Dexterity | (.47,2)(.38,11)(.28,15) |
| | | Spatial Orientation | (.39,7)(-.07,11)(.20,12) |
| Speed of Manipulation | (.32,15) | Finger Dexterity | (.45,15) |
| Square Marking | (.30,2)(.31,9)(.71,15) | Wrist-Finger Speed | (.29,2)(.46,9) |
| Ten Target Aiming (corrects) | (.66,2)(.31,9) | Manual Dexterity | (.05,2)(.42,18) |
| | | Speed of Arm Movement | (.72,9)(.50,18) |
| Two-Hand Coordination (Printed) | (.58,15) | | |

FACTOR: Arm-Hand Steadiness

Defined as : the ability to make precise, steady arm-hand movements of the type which minimize strength and speed. This ability is involved in tasks requiring maintenance of a steady arm position in space where the crucial feature is a minimum of tremor, as well as in tasks involving steadiness during limb movements.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Arm Drift | (.31,5) | | |
| Arm Tremor | (.36,5) | | |
| Cox Eye Board | (.47,15) | | |
| Hex Nut Steadiness | (.42,15) | | |
| Modified Target Aiming | (.34,5) | | |
| Precision Steadiness (errors) | (.50,2)(.56,5)(.43,6) (.34,18) | | |
| Punch Board | (.30,2)(.05 right hand,15) (.10 left hand,15) | | |
| Pursuit Confusion (errors) | (.36,6)(-.04,18) | Control Precision | (.04,6)(.37.18) |
| | | Pursuit Confusion Doublet | (.31,18) |

FACTOR: Arm-Hand Steadiness

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Santa Ana Peg Turning | (.05,2)(.32,15) | Aiming | (.17,7)(.33,15) |
| | | Finger Dexterity | (.16,2)(.42,7)(.46,12) (.06,15) |
| | | Manual Dexterity | (.47,2)(.38,11)(.28,15) |
| | | Spatial Orientation | (.39,7)(-.07,11)(.20,12) |
| Steadiness (Printed) | (.31,2) | | |
| Steadiness Aiming | (.60,2)(.40,18) | | |
| Steadiness Tremor | (.63,5) | | |
| Track Steadiness | (.56,15) | | |
| Track Tracing (errors) | (.61,2)(.61,5)(.50,6) (.42,18) | Finger Dexterity | (.21,2)(.35,7)(.18,18) |

FACTOR: Athletic Experience (General)

Defined as : a general background in athletics.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Athletic Experience Scale | (.89,8) | Athletic Experience Specific | (.32,8) |
| Athletic Versatility Index | (.64,8) | Athletic Experience Specific | (.45,8) |
| Basketball Experience | (.51,8) | Athletic Experience Specific | (.38,8 |
| Football Experience | (.45,8) | | |
| Squat Thrusts (in 30 seconds) | (.40,8) | Dynamic Strength | (.45,8) |
| Track (Field) Experience | (.63,8) | | |
| Track (Running) Experience | (.66,8) | | |

FACTOR: Athletic Experience (Specific)

**Defined as :** a background in baseball and basketball.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Athletic Experience Scale | (.32,8) | Athletic Experience General | (.89,8) |
| Athletic Versatility Index | (.45,8) | Athletic Experience General | (.64,8) |
| Baseball Experience | (.48,8) | | |
| Basketball Experience | (.38,8) | Athletic Experience General | (.51,8) |
| Height | (.32,8) | Dynamic Strength | (-.39,8) |
| | | Static Strength | (.42,8) |
| | | Trunk Strength | (-.31,8) |

FACTOR: Balance - Visual Cues

Defined as : the ability to use visual cues in maintaining balance.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Board Balance | (.29,8) | Dynamic Flexibility | (.30,8) |
| Foot Balance I | (.40,15) | Gross Body Coordination | (.36,15) |
| Foot Balance II | (.56,15) | | |
| One Foot Cross Balance - Eyes Open | (.55,8) | Gross Body Equilibrium | (.38,8) |
| One Foot Lengthwise Balance - Eyes Open | (.64,8)(.47,15) | | |
| Stick Balance | (.33,8) | | |
| Two Foot Cross Balance - Eyes Open | (.32,8) | Gross Body Equilibrium | (.53,8) |

FACTOR: Control Precision

Defined as : the ability to make sensitive, highly controlled (but not overcontrolled) positioning adjustments, primarily where larger muscle groups are involved. These adjustments are made to visual stimuli. This factor has been called Psychomotor Coordination I Fine Control Sensitivity and Control Manipulation Ability in other studies.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Analog Addition (Electronic) | (.31,17) | Movement Analysis | (.22,17) |
| | | Single Integration/ Differentiation Specific | (.23.17) |
| Approach to Stall (Flying) | (.45,14) | Kinesthetic Discrimination | (.51,14) |
| | | Multilimb Coordination | (.34,14) |
| Bimanual Matching | (.37,18) | | |
| Compensatory Balance | (.32,11) | Manual Dexterity | (.31,11) |
| Complex Coordination | (.36,2)(.45,3)(.35,6) (.44,7)(47,10)(.50,11) | Multilimb Coordination | (.30,6)(.38,18) |
| | | Response Orientation | (.44,3)(.43,4)(.09,6) (.22,11)(.23,18) |
| | | Spatial Orientation | (.13,3)(.40,4)(.46,7) (.39,10)(.16,11)(.45,12) (.34,18) |
| | | Speed of Arm Movement | (.09,2)(.37,3)(.21,6) (.09,7)(.37,10)(.09,18) |
| Control Adjustment | (.46,6) | | |

FACTOR: Control Precision

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Control Sensitivity | (.38,18) | | |
| Coordination Exercise (Flying) | (.41,14) | Multilimb Coordination | (.60,14) |
| Dial Setting | (.40,6) | Response Orientation | (.43,6) |
| Dynamic Balance | (.35,2) | | |
| Landing Characteristic Stall (Flying) | (.68,14) | Kinesthetic Discrimination | (.38,14) |
| Motor Judgment | (.40,6) | Rate Control | (.40,6) |
| 90° Climbing Turn (Flying) | (.68,14) | Spatial Orientation | (.41,14) |
| Plane Control | (.38,3) | Multilimb Coordination | (.41,6) |
| | | Speed of Arm Movement | (.49,3) |
| Pursuit Confusion (time-on-target) | (.12,6)(.48,11)(.38,18) | Pursuit Confusion Doublet | (.35,18) |
| | | Rate Control | (.37,6)(.17,11) |
| Pursuit Confusion (errors) | (.04,6)(37,18) | Arm-Hand Steadiness | (.36,6)(-.04,18) |

FACTOR: Control Precision

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| | | Pursuit Confusion Doublet | (.31,18) |
| Rate Control | (.30,6)(.01,7)(.24,11) | Rate Control | (.30,6)(.72,7)(.58,11) |
| | | Spatial Orientation | (.17,7)(.47,18) |
| Rotary Pursuit | (.26,3)(.49,7)(.60,18) | Manual Dexterity | (.17,2)(.35,11)(-.06,18) |
| | | Speed of Arm Movement | (.22,2)(.47,3)(.17,6)(.20,7)(.34,10)(-.02,18) |
| Rudder Control | (.45,2)(.44,6)(.40,11)(.52,17)(.40,18) | Movement Prediction | (.23,17) |
| | | Multilimb Coordination | (.48,6)(.36,17) |
| | | Single Integration/ Differentiation Specific | (.21,17) |
| Rudder Control Stall (Flying) | (.41,14) | Kinesthetic Discrimination | (.40,14) |
| | | Spatial Orientation | (.31,14) |
| Single Differentiation/ Integration (Electronic) | (.40,17) | | |
| Steep Turn-360° (Flying) | (.47,14) | Rate Control | (.46,14) |

FACTOR: Control Precision

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Slow Flight Turn (Flying) | (.31,14) | Kinesthetic Discrimination | (.30,14) |
| | | Multilimb Coordination | (.37,14) |
| | | Response Orientation | (.41,14) |
| Take off (Flying) | (.54,14) | Multilimb Coordination | (.50,14) |
| Three-Point Landing (Flying) | (.42,14) | Rate Control | (.35,14) |
| Time Sharing Mechanical | (.26,17) | Time Sharing | (.79,17) |
| Track Tracing (errors) | (.16,2)(.29,6)(.42,7) | Arm-Hand Steadiness | (.61,2)(.61,5)(.50,6) (.42,18) |
| | | Finger Dexterity | (.21,2)(.35,7)(.18,18) |
| Two-Hand Coordination | (.25,6)(.46,11) | Rate Control | (.32,6)(.17,11) |
| Two Plate Tapping | (.41,18) | Manual Dexterity | (.24,2)(.35,18) |
| | | Speed of Arm Movement | (.54,2)(-.05,18) |
| | | Wrist-Finger Speed | (.36,2) |

FACTOR: Control Precision

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Visual Pursuit | (.24,3)(.36,7)(.20,10) | Perceptual Speed | (.46,3)(.28,7)(.50,10)(.35,18) |
| | | Spatial Orientation | (.17,3)(.22,7)(.35,18) |

FACTOR: Dynamic Balance

Defined as : the ability to maintain balance while in the process of some performance, such as jumping.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Jump and Balance | (.53, 15) | Explosive Strength | (.35, 15) |
| Jump and Click Heels | (.54, 15) | Jump Performance | (.50, 15) |
| Rate of Jump | (.46, 15) | Explosive Strength | (.35, 15) |

FACTOR: Dynamic Flexibility

Defined as : the ability to make repeated, rapid, flexing or stretching movements, where the extent of the movements is either short or long.

| Identifying Test, Loadings, and References | Loading of This Test on Other Factors |
|---|---|
| Bend, Twist and Touch (.50,8) | |
| Block Transfer (.56,8) | |
| Board Balance (.30,8) | Balance - Visual Cues (.29,8) |
| Lateral Bend (.58,8) | |
| Leg Circling (.48,8) | |
| One Foot Tapping (.58,8) | |
| Soccer Dribble (.32,8) | |
| Squat, Twist and Touch (.53,8) | |

FACTOR: Dynamic Strength

Defined as : the ability to exert muscular force repeatedly or continuously over time.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Bent Arm Hang | (.73,8) | | |
| Chins (in 20 seconds) | (.78,8) | Explosive Strength | (.40,8) |
| Chins (to limit) | (.81,8) | Gross Body Coordination | (.52,15) |
| | | Limb Strength | (.55,15) |
| Dips (in 10 seconds) | (.70,8) | Explosive Strength | (.33,8) |
| Dips (to limit) | (.63,8) | | |
| 50 Yard Dash | (.44,8) | Explosive Strength | (.75,8) |
| Height | (-.39,8) | Athletic Experience Specific | (.32,8) |
| | | Static Strength | (.42,8) |
| | | Trunk Strength | (-.31,8) |
| Hold Half Push-up | (.68,8) | | |
| Hold Half Sit-up | (.30,8) | Trunk Strength | (.45,8) |
| Leg Lifts (in 20 seconds) | (.32,8) | Trunk Strength | (.47,8) |

FACTOR: Dynamic Strength

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Leg Raiser | (.35, 8) | Trunk Strength | (.43, 8)(.43, 15) |
| Push-ups (in 15 seconds) | (.68, 8) | | |
| Push-ups (to limit) | (.74, 8) | Limb Strength | (.59, 15) |
| | | Trunk Strength | (.43, 15) |
| Push Weights - Arms (in 20 seconds) | (.38, 8) | Static Strength | (.51, 8) |
| | | Weight Balance | (.44, 8) |
| Rope Climb (in 6 seconds) | (.67, 8) | Explosive Strength | (.41, 8) |
| Shuttle Run | (.39, 8) | Explosive Strength | (.77, 8)(.63, 8) |
| Sit-ups (in 30 seconds) | (.31, 8) | Explosive Strength | (.33, 8) |
| Squat Thrusts (in 30 seconds) | (.45, 8) | Athletic Experience General | (.40, 8) |
| Standing Broad Jump | (.35, 8) | Explosive Strength | (.66, 8) |
| Vertical Jump | (.30, 8) | Explosive Strength | (.64, 8) |
| Weight | (-.43, 8) | Static Strength | (.70, 8) |

FACTOR: Explosive Strength

Defined as : the ability to expend a maximum of energy in one explosive act. It is distinguished from the other strength factors in that it requires mobilization of energy for a burst of effort, rather than continuous strain, stress, or repeated exertion.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Arm Circling | (.52, 8) | Speed of Limb Movement | (.39, 8) |
| Backward Jump | (.46, 15) | | |
| Chins (in 20 seconds) | (.40, 8) | Dynamic Strength | (.78, 8) |
| Circle Run | (.59, 8) | | |
| Dips (in 10 seconds) | (.33, 8) | Dynamic Strength | (.70, 8) |
| Dodge Run | (.69, 8) | | |
| 50 Yard Dash | (.75, 8) | Dynamic Strength | (.44, 8) |
| Figure 8 Duck | (.68, 8) | | |
| Grass Drill | (.62, 8) | | |
| Hurdle Jump | (.39, 15) | Gross Body Coordination | (.52, 15) |
| | | Jump Performance | (.33, 15) |
| Jump and Balance | (.35, 15) | Dynamic Balance | (.53, 15) |
| Jump and Touch | (.65, 15) | Jump Performance | (.32, 15) |
| | | Limb Strength | (.33, 15) |

FACTOR: Explosive Strength

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Plate Tapping | (.39,8) | Speed of Limb Movement | (.44,8) |
| Rate of Jump | (.35,15) | Dynamic Balance | (.46,15) |
| Rope Climb (in 6 seconds) | (.41,8) | Dynamic Strength | (.67,8) |
| Shuttle Run | (.77,8)(.63,8) | Dynamic Strength | (.39,8) |
| Sit-ups (in 30 seconds) | (.33,8) | Dynamic Strength | (.78,8) |
| Softball Throw | (.54,8) | | |
| Standing Broad Jump | (.66,8) | Dynamic Strength | (.35,8) |
| Table Vault | (.34,15) | Jump Performance | (.32,15) |
| | | Trunk Flexibility | (.37,15) |
| 10 Yard Dash | (.70,8) | | |
| Vertical Jump | (.64,8) | Dynamic Strength | (.30,8) |

FACTOR: Extent Flexibility

Defined as : the ability to stretch the trunk and back muscles as far as possible, without speed, either laterally, forward, or backward.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Abdominal Stretch | (.55,8) | | |
| Toe Touching | (.39,8) | Leg Flexibility | (.63,15) |
| Twist and Touch | (.49,8) | | |

FACTOR: Finger Dexterity

Defined as : the ability to make rapid, skillful, controlled manipulative movements of small objects where the fingers are involved primarily.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Aiming | (.12,2)(.35,7)(.30,9) | Aiming | (.63,2)(.36,7)(.57,9) |
| | | Wrist-Finger Speed | (.45,2)(.52,9) |
| Ball and Pipe | (.45,15) | | |
| Minnesota Rate of Manipulation (Placing) | (.31,2)(.37,9)(.36,18) | Aiming | (.34,9) |
| | | Manual Dexterity | (.73,1)(.32,2)(.53,9) (.38,18) |
| | | Speed of Arm Movement | (.36,2)(.24,9)(-.13,18) |
| Minnesota Rate of Manipulation (Turning) | (.34,2)(.34,9)(.27,18) | Manual Dexterity | (.61,1)(.38,2)(.52,9) (.40,18) |
| Nut and Bolt | (.39,15) | Mechanical Experience | (.32,10) |
| O'Connor Finger Dexterity | (.53,2)(.59,9)(.49,18) | Manual Dexterity | (.50,1)(.25,2) |
| | | Visual Feedback | (.43,1) |
| Pin Stick | (.19,2)(.34,9) | | |
| Purdue Pegboard (sum of scores on the four variations) | (.43,18) | Manual Dexterity | (.33,18) |

FACTOR: Finger Dexterity

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Purdue Pegboard (Assembly) | (.55, 2)(.43, 7)(.59, 9) (.35, 12) | Manual Dexterity | (.21, 2)(.32, 9) |
| | | Perceptual Speed | (.31, 7) |
| Purdue Pegboard (Both Hands) | (.61, 2)(.66, 9) | Manual Dexterity | (.63, 1)(.21, 2) |
| Purdue Pegboard (Left Hand) | (.58, 2)(.55, 9) | | |
| Purdue Pegboard (Right Hand) | (.46, 2)(.60, 9) | | |
| Restricted Manipulation | (.35, 15) | | |
| Santa Ana Finger Dexterity | (.16, 2)(.42, 7)(.46, 12) (.06, 15) | Aiming | (.17, 7)(.33, 15) |
| | | Manual Dexterity | (.47, 2)(.38, 11)(.28, 15) |
| | | Spatial Orientation | (.39, 7)(-.07, 11)(.20, 12) |
| Speed of Identification | (.33, 7)(.10, 18) | Perceptual Speed | (.46, 3)(.43, 4)(.45, 7) (.47, 10)(.53, 18) |
| | | Spatial Orientation | (.37, 3)(.32, 7)(.35, 10) (.16, 12) |
| | | Verbal Comprehension | (.37, 12)(.20, 18) |
| | | Visualization | (.38, 3)(.29, 10)(.06, 18) |

FACTOR: Finger Dexterity

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Speed of Manipulation (Removing) | (.45, 15) | Aiming | (.32, 15) |
| Track Tracing (errors) | (.21, 2)(.35, 7)(.18, 18) | Arm-Hand Steadiness | (.61, 2)(.61, 5)(.50, 6) (.42, 18) |
| | | Control Precision | (.16, 2)(.29, 6)(.42, 7) |

FACTOR: Gross Body Coordination

Defined as : the ability to coordinate movements where most of the entire body is involved. It requires that the trunk as well as the limbs be employed simultaneously in accomplishing the task.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Cable Jump | (.56,15) | | |
| Chinning (to limit) | (.52,15) | Dynamic Strength | (.81,8) |
| | | Limb Strength | (.55,15) |
| Foot Balance I | (.36,15) | Balance - Visual Cues | (.40,15) |
| Hurdle Jump | (.52,15) | Explosive Strength | (.39,15) |
| | | Jump Performance | (.33,15) |
| Rail Walking | (.31,15) | Gross Body Equilibrium | (.44,8) |
| Rising From Supine | (.57,15) | Leg Flexibility | (.38,15) |

FACTOR: Gross Body Equilibrium

Defined as : the ability to maintain body equilibrium.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| One Foot Cross Balance - Eyes Closed | (.54,8) | | |
| One Foot Cross Balance - Eyes Open | (.38,8) | Balance - Visual Cues | (.55,8) |
| One Foot Lengthwise Balance - Eyes Closed | (.72,8) | | |
| Rail Walking - Eyes Open | (.44,8) | Gross Body Coordination | (.31,15) |
| Two Foot Cross Balance - Eyes Closed | (.64,8) | | |
| Two Foot Cross Balance - Eyes Open | (.53,8) | Balance - Visual Cues | (.32,8) |

FACTOR: Integration (Tentative)

Defined as : the ability to utilize and coordinate a number of disparate cues in activities quickly and accurately in order to produce an appropriate, integrated single response.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Complex Movements (Printed) | (. 30, 18) | Visualization | (. 32, 11)(. 34, 18) |
| Coordinate Movements (Printed) | (. 40, 18) | Spatial Orientation | (. 36, 11)(. 36, 18) |
| Directional Control (Printed) | (. 30, 18) | Spatial Orientation<br>Visualization | (. 38, 11)(. 34, 18)<br>(. 34, 11) |

FACTOR: Jump Performance (Tentative)

Defined as : the ability to perform a task while in the process of jumping.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Hurdle Jump | (.33,15) | Explosive Strength | (.39,15) |
| | | Gross Body Coordination | (.52,15) |
| Jump and Click Heels | (.50,15) | Dynamic Balance | (.54,15) |
| Jump and Touch | (.32,15) | Explosive Strength | (.65,15) |
| | | Limb Strength | (.33,15) |
| Jump and Turn | (.57,15) | | |
| Table Vault | (.32,15) | Explosive Strength | (.34,15) |
| | | Trunk Flexibility | (.37,15) |

FACTOR: Leg Flexibility

Defined as : the capacity of the leg muscles to resist deformity and to recover quickly from undue strain.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Backing Down Wall | (.33,15) | Trunk Flexibility | (.50,15) |
| Kicking Height | (.62,15) | | |
| Leg Bend | (.51,15) | | |
| Rising from Supine | (.38,15) | Gross Body Coordination | (.57,15) |
| Toe Touching | (.63,15) | Extent Flexibility | (.39,15) |

FACTOR: Limb Strength (Tentative)

Defined as : strength of arms and legs.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Chinning (to limit) | (.55, 15) | Dynamic Strength | (.81, 8) |
| | | Gross Body Coordination | (.52, 15) |
| Jump and Touch | (.33, 15) | Explosive Strength | (.65, 15) |
| | | Jump Performance | (.32, 15) |
| Push-ups (to limit) | (.59, 15) | Dynamic Strength | (.74, 8) |
| | | Trunk Strength | (.43, 15) |

FACTOR: Kinesthetic Discrimination

Defined as : the ability to discriminate changes in the position of limbs and body, and changes in forces applied thereto. This factor has also been called Postural Discrimination and Proprioception.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Approach to Stall (Flying) | (.51, 14) | Control Precision | (.45, 14) |
| | | Multilimb Coordination | (.34, 14) |
| Climbing Turn from Level (Flying) | (.33, 14) | Multilimb Coordination | (.56, 14) |
| Forced Landing (Flying) | (.37, 14) | Multilimb Coordination | (.49, 14) |
| | | Spatial Orientation | (.53, 14) |
| Gliding Turn (Flying) | (.46, 14) | Multilimb Coordination | (.51, 14) |
| | | Spatial Orientation | (.38, 14) |
| Landing Characteristic Stall (Flying) | (.38, 14) | Control Precision | (.68, 14) |
| Level-off from Climbing Turn (Flying) | (.32, 14) | Multilimb Coordination | (.39, 14) |
| | | Spatial Orientation | (.52, 14) |
| No Slip Back, Distance-in-Error (Vehicle Driving) | (.39, 16) | | |

FACTOR: Kinesthetic Discrimination

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Non-Visual, Distance-in-Error (Vehicle Driving) | (.52, 16) | Spatial Orientation | (.46, 16) |
| Postural Discrimination - Angular | (.55, 2) | | |
| Postural Discrimination - Vertical | (.48, 2) | | |
| Power-off Stall (Flying) | (.61, 14) | Multilimb Coordination | (.33, 14) |
| | | Response Orientation | (.43, 14) |
| Power-on Stall (Flying) | (.43, 14) | Multilimb Coordination | (.45, 14) |
| | | Rate Control | (.33, 14) |
| Rudder Control Stall (Flying) | (.40, 14) | Control Precision | (.41, 14) |
| | | Spatial Orientation | (.31, 14) |
| Slow-Flight Turn (Flying) | (.30, 14) | Control Precision | (.31, 14) |
| | | Multilimb Coordination | (.37, 14) |
| | | Response Orientation | (.41, 14) |
| Spin (Flying) | (.43, 14) | Rate Control | (.43, 14) |

FACTOR: Manual Dexterity

Defined as : the ability to make skillful, controlled arm-hand manipulations of larger objects.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Bowling Green Tweezer Dexterity | (.37,1) | Visual Feedback | (.53,1) |
| Compensatory Balance | (.31,11) | Control Precision | (.32,11) |
| Discrimination Reaction Time (Mechanical) | (.10,2)(.34,11)(.01,18) | Response Orientation | (.28,3)(.53,4)(.67,6) (.50,11)(.29,18) |
| | | Spatial Orientation | (.38,3)(.38,4)(.72,7) (.52,10)(.37,11)(.33,12) (.14,18) |
| | | Speed of Arm Movement | (.05,2)(.46,3)(.03,6) (-.03,7)(.25,10)(.07,18) |
| | | Visualization | (.16,3)(.23,10)(.10,11) (.34,18) |
| Discrimination Reaction Time (Printed) | (.26,2)(.34,9)(.04,11) (.15,18) | Perceptual Speed | (.35,10)(.14,18) |
| | | Response Orientation | (.42,4)(.52,6)(.41,11) (.38,18) |
| | | Wrist-Finger Speed | (.14,2)(.30,9) |
| Dowel Manipulation | (.60,1)(.40,15) | | |

FACTOR: Manual Dexterity

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Marble Board | (.51, 15) | | |
| O'Connor Finger Dexterity | (.50, 1)(.25, 2) | Finger Dexterity | (.53, 2)(.59, 9)(.49, 18) |
| | | Visual Feedback | (.43, 1) |
| Pin Moving | (.32, 1) | Visual Feedback | (.31, 1) |
| Placing, Tweezer | (.37, 1) | | |
| Purdue Pegboard - Assembly | (.32, 9)(.21, 2) | Finger Dexterity | (.55, 2)(.43, 7)(.59, 9)(.35, 12) |
| | | Perceptual Speed | (.31, 7) |
| Purdue Pegboard - Both Hands | (.63, 1)(.21, 2) | Finger Dexterity | (.61, 2)(.66, 9) |
| Purdue Pegboard - Left Hand | (.13, 2) | Finger Dexterity | (.58, 2)(.55, 9) |
| Purdue Pegboard - Right Hand | (.19, 2) | Finger Dexterity | (.46, 2)(.60, 9) |
| Purdue Pegboard - Non-Preferred Hand | (.68, 1) | | |
| Purdue Pegboard - Sum of Scores | (.33, 18) | Finger Dexterity | (.43, 18) |

FACTOR: Manual Dexterity

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Rate of Manipulation-Placing | (.73, 1)(.32, 2)(.53, 9)(.38, 18) | Aiming | (.34, 9) |
| | | Finger Dexterity | (.31, 2)(.37, 9)(.36, 18) |
| | | Speed of Arm Movement | (.36, 2)(.24, 9)(-.13, 18) |
| Rate of Manipulation-Turning | (.61, 1)(.38, 2)(.52, 9)(.40, 18) | Finger Dexterity | (.34, 2)(.34, 9)(.27, 18) |
| Rotary Pursuit | (.17, 2)(.35, 11)(-.06, 18) | Control Precision | (.26, 3)(.49, 7)(.60, 18) |
| | | Speed of Arm Movement | (.22, 2)(.47, 3)(.17, 6)(.20, 7)(.34, 10)(-.02, 18) |
| Santa Ana Finger Dexterity | (.47, 2)(.38, 11)(.28, 15) | Aiming | (.17, 7)(.33, 15) |
| | | Finger Dexterity | (.16, 2)(.42, 7)(.46, 12)(.06, 15) |
| | | Spatial Orientation | (.39, 7)(-.07, 11)(.20, 12) |
| Ten Target Aiming (corrects) | (.05, 2)(.42, 18) | Aiming | (.31, 9) |
| | | Speed of Arm Movement | (.66, 2)(.72, 9)(.50, 18) |
| Ten Target Aiming (errors) | (.43, 2)(.35, 18) | Speed of Arm Movement | (-.35, 2)(-.70, 9)(.63, 18) |

FACTOR: Manual Dexterity

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Two Plate Tapping | (.24, 2)(.35, 18) | Control Precision | (.41, 18) |
| | | Speed of Arm Movement | (.54, 2)(-.05, 18) |
| | | Wrist-Finger Speed | (.36, 2) |
| VDL Rings | (.44, 15) | | |

FACTOR: Mechanical Experience

Defined as : a knowledge of tools and an understanding of mechanical principles and the proper use of tools and mechanical devices.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Dial and Table Reading | (.30,10) | Numerical Facility | (.60,10) |
| | | Perceptual Speed | (.32,10) |
| Forced Landings | (.35,18) | Response Orientation | (.36,18) |
| General Mechanics | (.64,3)(.81,7)(.62,10) (.47,18) | Visualization | (.09,3)(.06,10)(.38,18) |
| Instrument Comprehension | (.19,3)(.41,7)(.16,10) (.16,18) | Perceptual Speed | (.29,3)(.15,7)(.35,10) (.15,18) |
| | | Spatial Orientation | (.49,3)(.69,4)(.50,7) (.46,10)(.37,12)(.47,18) |
| | | Verbal Comprehension | (.36,12)(.24,18) |
| | | Visualization | (.20,10)(.33,18) |
| Mechanical Comprehension | (.47,18) | Visualization | (.38,18) |
| Mechanical Principles | (.61,3)(.49,10) | Verbal Comprehension | (.43,12) |
| | | Visualization | (.40,3)(.41,4)(.41,10) |
| Nut and Bolt | (.32,10) | Finger Dexterity | (.39,15) |
| Tool Functions | (.83,7) | | |

FACTOR: Movement Analysis

Defined as : the ability to analyze motion having constant velocity and constant acceleration characteristics.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Analog Addition (Electronic) | (.22, 17) | Control Precision | (.31, 17) |
| | | Single Integration/ Differentiation Specific | (.23, 17) |
| Double Differentiation (Electronic) | (.58, 17) | | |
| Multiplication by a Constant (Electronic) | (.21, 17) | Multiplication by a Constant (Electronic) Specific | (.41, 17) |
| Single Differentiation (Electronic) | (.60, 17) | | |
| Tracking (Criterion) | (.24, 17) | Movement Prediction | (.33, 17) |
| | | Multilimb Coordination | (.55, 17) |

FACTOR: Movement Prediction

Defined as : the ability to take information from second order (acceleration) systems and to predict through time on the basis of this information.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Double Differentiation/ Integration (Mechanical) | (. 43, 17) | | |
| Rudder Control | (. 23, 17) | Control Precision | (. 45, 2)(. 44, 6)(. 40, 11) (. 52, 17)(. 40, 18) |
| | | Multilimb Coordination | (. 48, 6)(. 36, 17) |
| | | Single Integration/ Differentiation Specific | (. 21, 17) |
| Time Sharing (Electronic) | (-. 30, 17) | | |
| Tracking (Criterion) | (. 33, 17) | Movement Analysis | (. 24, 17) |
| | | Multilimb Coordination | (. 55, 17) |

FACTOR: Multilimb Coordination

Defined as : the ability to coordinate the movements of two hands, two feet, or combinations of hands and feet simultaneously. This factor has also been called Psychomotor Coordination II.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Approach to Stall (Flying) | (.34,14) | Control Precision | (.45,15) |
| | | Kinesthetic Discrimination | (.51,14) |
| Climbing Turn from Level (Flying) | (.56,14) | Kinesthetic Discrimination | (.33,14) |
| Complex Coordination | (.30,6)(.38,18) | Control Precision | (.36,2)(.45,3)(.35,6) (.44,7)(.47,10)(.50,11) |
| | | Response Orientation | (.44,3)(.43,4) (.09,6) (.22,11)(.23,18) |
| | | Spatial Orientation | (.13,3)(.40,4)(.46,7) (.39,10) (.16,11)(.45,12) (.34,18) |
| | | Speed of Arm Movement | (.09,2)(.37,3) (.21,6) (.09,7)(.37,10)(.09,18) |
| Coordination Exercise (Flying) | (.60,14) | Control Precision | (.41,14) |
| Forced Landing (Flying) | (.49,14) | Kinesthetic Discrimination | (.37,14) |
| | | Spatial Orientation | (.53,14) |

**FACTOR:** Multilimb Coordination

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Gliding Turn (Flying) | (.51,14) | Kinesthetic Discrimination | (.46,14) |
| | | Spatial Orientation | (.38,14) |
| Hours of Driving (Vehicle Driving) | (.36,16) | | |
| Level-off from Climbing Turn (Flying) | (.39,14) | Control Precision | (.32,14) |
| | | Spatial Orientation | (.52,14) |
| Level-off from Gliding Turn (Flying) | (.42,14) | Response Orientation | (.48,14) |
| Plane Control | (.41,6) | Control Precision | (.38,3) |
| | | Speed of Arm Movement | (.49,3) |
| Power-off Stall (Flying) | (.33,14) | Kinesthetic Discrimination | (.61,14) |
| | | Response Orientation | (.43,14) |
| Power-on Stall (Flying) | (.45,14) | Kinesthetic Discrimination | (.43,14) |
| | | Rate Control | (.33,14) |

**FACTOR:** Multilimb Coordination

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Rudder Control-Single Target | (.52,6) | | |
| Rudder Control-Triple Target | (.48,6)(.36,17) | Movement Prediction | (.23,17) |
| | | Control Precision | (.45,2)(.44,6)(.40,11)(.52,17)(.40,18) |
| | | Single Integration/Differentiation Specific | (.21,17) |
| Rudder Control (sum of scores) | (.40,18) | | |
| Slow Flight Recovery (Flying) | (.36,14) | Response Orientation | (.41,14) |
| | | Spatial Orientation | (.47,14) |
| Slow Flight Turn (Flying) | (.37,14) | Control Precision | (.31,14) |
| | | Kinesthetic Discrimination | (.30,14) |
| | | Response Orientation | (.41,14) |
| Straight and Level (Flying) | (.38,14) | Rate Control | (.41,14) |
| | | Response Orientation | (.42,14) |
| Take-off (Flying) | (.50,14) | Control Precision | (.54,14) |

**FACTOR:** Multilimb Coordination

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Tracking (Criterion) | (.55,17) | Movement Analysis | (.24,17) |
| | | Movement Prediction | (.33,17) |
| Traffic Pattern at Home Field (Flying) | (.43,14) | Response Orientation | (.48,14) |
| | | Spatial Orientation | (.39,14) |
| Two-Hand Coordination | (.33,6),(.30,18) | Control Precision | (.25,6)(.46,11) |
| | | Rate Control | (.32,6)(.17,11) |
| Two-Hand Pursuit | (.32,6) | Rate Control | (.37,6) |

FACTOR: Multiplication by a Constant (Electronic) Specific

Defined as : performance on the Multiplication by a Constant (Electronic) Test.

| Identifying Test, Loadings, and References | Loading of This Test on Other Factors |
|---|---|
| Multiplication by a Constant (Electronic) (.41, 17) | Movement Analysis (.21, 17) |

FACTOR: Numerical Facility

Defined as : the ability to locate and use numbers as well as to perform computations.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Decoding | (.35, 10) | | |
| Dial and Table Reading | (.60, 10) | Mechanical Experience | (.30, 10) |
| | | Perceptual Speed | (.32, 10) |
| Log Book Accuracy | (.31, 10) | | |
| Numerical Operations II | (.66, 10) | | |

FACTOR: Perceptual Speed

Defined as : the ability to make rapid comparisons of visual detail.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Coordination (Printed) | (.42,11) | | |
| Dial and Table Reading | (.32,10) | Mechanical Experience | (.30,10) |
| | | Numerical Facility | (.60,10) |
| Discrimination Pursuit (Printed) | (.55,11) | | |
| Discrimination Reaction Time (Printed) | (.35,11)(.14,18) | Manual Dexterity | (.26,2)(.34,9)(.04,11) (.15,18) |
| | | Response Orientation | (.42,4)(.52,6)(.41,11) (.38,11) |
| | | Wrist-Finger Speed | (.14,2)(.30,9) |
| Following Directions | (.31,18) | | |
| Instrument Comprehension | (.29,3)(.15,7)(.35,10) (.15,18) | Mechanical Experience | (.19,3)(.41,7)(.16,10) (.16,18) |
| | | Spatial Orientation | (.49,3)(.69,4)(.50,7) (.46,10)(.37,12)(.47,18) |
| | | Verbal Comprehension | (.36,12)(.24,18) |
| | | Visualization | (.20,10)(.33,18) |

FACTOR: Perceptual Speed

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Pattern Comprehension | (.36, 3)(.23, 10) | Spatial Orientation | (.31, 3)(.40, 4)(.33, 10) (.24, 12) |
| | | Verbal Comprehension | (.46, 12)(.16, 18) |
| | | Visualization | (.60, 3)(.55, 4)(.60, 10) (.58, 18) |
| Purdue Pegboard - Assembly | (.31, 7) | Finger Dexterity | (.55, 2)(.43, 7)(.59, 9) (.35, 12) |
| | | Manual Dexterity | (.21, 2)(.32, 9) |
| Response Orientation Test ($0^{o}$) | (.47, 4) | | |
| Response Orientation Test ($45^{o}$) | (.40, 4) | Spatial Orientation | (.34, 4) |
| Response Orientation Test ($315^{o}$) | (.36, 4) | | |
| Signal Discrimination | (.40, 11) | Spatial Orientation | (.35, 11) |
| | | Response Orientation | (.52, 11) |
| Spatial Orientation | (.45, 10)(.30, 18) | Spatial Orientation | (.35, 10)(.34, 18) |

FACTOR: Perceptual Speed

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Spatial Visualization | (.35, 4) | Visualization | (.73, 4) |
| Speed of Identification | (.46, 3)(.43, 4)(.45, 7)(.47, 10)(.53, 18) | Finger Dexterity | (.33, 7)(.10, 18) |
| | | Spatial Orientation | (.37, 3)(.32, 7)(.35, 10)(.16, 12) |
| | | Verbal Comprehension | (.37, 12)(.20, 18) |
| | | Visualization | (.38, 3)(.29, 10)(.06, 18) |
| Visual Pursuit | (.46, 3)(.28, 7)(.50, 10)(.35, 18) | Control Precision | (.24, 3)(.36, 7)(.20, 10) |
| | | Spatial Orientation | (.17, 3)(.22, 7)(.35, 18) |

FACTOR: Position Estimation (Highly Tentative)

Defined as : the ability to move a limb to a specified position, where this position must be estimated rather than reproduced from an immediately experienced limb position.

| Identifying Test, Loadings, and References | Loading of This Test on Other Factors |
|---|---|
| Control Movement - Estimate (.48, 5) | |
| Knob Positioning - Estimate (.42, 5) | |
| Rotary Positioning - Estimate (.45, 5) | |

FACTOR: Position Reproduction

Defined as : the ability to remove one's arm or a control from a position and then to return to that same position.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors |
|---|---|---|
| Control Movement - Respond | (. 32, 5) | |
| Direction Tracing | (. 39, 5) | |
| Knob Positioning - Respond | (. 34, 5) | |
| Stick Positioning | (. 30, 5) | |

FACTOR: Pursuit Confusion Doublet

Defined as : performance on the Pursuit Confusion Test. The two scores were not expected to define the same factor.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Pursuit Confusion (time-on-target) | (. 35, 18) | Control Precision | (. 12, 6)(. 48, 11)(. 38, 18) |
| | | Rate Control | (. 37, 6)(. 17, 11) |
| Pursuit Confusion (errors) | (. 31, 18) | Arm-Hand Steadiness | (. 36, 6)(-. 04, 18) |
| | | Control Precision | (. 04, 6)(. 37, 18) |

FACTOR: Rate Control

Defined as : the ability to make continuous anticipatory motor adjustments relative to changes in speed and direction of a continuously moving target or object. A common feature of all the tasks which measure this factor is the element of pursuit which seems to be involved.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Compensatory Balance | (.39,11) | Control Precision | (.32,11) |
| | | Manual Dexterity | (.31,11) |
| Motor Judgment | (.40,6) | Control Precision | (.40,6) |
| Multidimensional Pursuit-Bank and Altitude | (.37,6) | Response Orientation | (.32,6) |
| Power-on Stall (Flying) | (.33,14) | Kinesthetic Discrimination | (.43,14) |
| | | Multilimb Coordination | (.45,14) |
| Pursuit Confusion (time-on-target) | (.37,6)(.17,11) | Control Precision | (.12,6)(.48,11)(.38,18) |
| | | Pursuit Confusion Doublet | (.35,18) |
| Rate Control | (.30,6)(.72,7)(.58,11) | Control Precision | (.30,6)(.01,7)(.24,11) |
| | | Spatial Orientation | (.17,7)(.47,18) |

FACTOR: Rate Control

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Single Dimension Pursuit Meter | (-.06, 6)(.64, 7)(.55, 11) | | |
| Spin (Flying) | (.43, 14) | Kinesthetic Discrimination | (.43, 14) |
| Steep Turn - 360° (Flying) | (.46, 14) | Control Precision | (.47, 14) |
| Straight and Level (Flying) | (.41, 14) | Multilimb Coordination | (.38, 14) |
| | | Response Orientation | (.42, 14) |
| Straight and Level Gear Check (Flying) | (.34, 14) | Spatial Orientation | (.47, 14) |
| Traffic Pattern at Auxiliary Field (Flying) | (.31, 14) | Response Orientation | (.49, 14) |
| | | Spatial Orientation | (.46, 14) |
| Three-Point Landing (Flying) | (.35, 14) | Control Precision | (.42, 14) |
| Two-Hand Coordination | (.32, 6)(.17, 11) | Control Precision | (.25, 6)(.46, 11) |
| | | Multilimb Coordination | (.33, 6)(.30, 18) |
| Two-Hand Pursuit | (.37, 6) | Multilimb Coordination | (.32, 6) |

FACTOR: Reaction Time

Defined as : the speed with which a person can react to a stimulus when it appears.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Auditory Reaction Time | (.68,2)(.63,6)(.68,12) (.51,18) | | |
| Jump Auditory Reaction Time | (.64,6)(.70,12)(.48,18) | Speed of Arm Movement | (.44,6)(.31,18) |
| Jump Visual Reaction Time | (.73,2)(.54,6)(.73,12) (.52,18) | Speed of Arm Movement | (.19,2)(.65,3)(.54,6) (.40,7)(.54,10)(.36,18) |
| No-Slip Back, Errors (Vehicle Driving) | (.56,16) | | |
| No-Slip Forward, Errors (Vehicle Driving) | (.47,16) | | |
| Visual Reaction Time | (.56,6)(.72,12)(.48,18) | | |

FACTOR: Response Orientation

Defined as : the ability to choose and perform the proper movement or direction of movement from several alternatives. It does not involve the interpretation of the spatial characteristics of the stimulus.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Choice Reaction Time | (.39,18) | | |
| Complex Coordination | (.44,3)(.43,4)(.09,6)<br>(.22,11)(.23,18) | Control Precision | (.36,2)(.45,3)(.35,6)<br>(.44,7)(.47,10)(.50,11) |
| | | Multilimb Coordination | (.30,6)(.38,18) |
| | | Spatial Orientation | (.13,3)(.40,4)(.46,7)<br>(.39,10)(.16,11)(.45,12)<br>(.34,18) |
| | | Speed or Arm Movement | (.09,2)(.37,3)(.21.6)<br>(.09,7)(.37,10)(.09,18) |
| Complex Multiple Reaction | (.41,11) | | |
| Dial Setting | (.43,6) | Control Precision | (.40,6) |
| Direction Control | (.58,4) | Spatial Orientation | (.34,4)(.39,11)(.24,18) |
| | | Visualization | (.44,11)(.34,18) |
| Discrimination Reaction Time (Mechanical) | (.28,3)(.53,4)(.67,7)<br>(.50,11)(.29,18) | Manual Dexterity | (.10,2)(.34,11)(.01,18) |
| | | Spatial Orientation | (.38,3)(.38,4)(.72,7)<br>(.52,10)(.37,11)(.33,12)<br>(.14,18) |

FACTOR: Response Orientation

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Discrimination Reaction Time (Printed) | (.42,4)(.52,6)(.41,11)(.38,18) | Manual Dexterity | (.26,2)(.34,9)(.04,11)(.15,18) |
| | | Perceptual Speed | (.35,10)(.14,18) |
| | | Wrist-Finger Speed | (.14,2)(.30,9) |
| Forced Landings | (.36,18) | Mechanical Experience | (.35,18) |
| Kinesthetic Coordination | (.40,3) | | |
| Level-off from Gliding Turn (Flying) | (.48,14) | Multilimb Coordination | (.42,14) |
| Maze, Direction Changes (Vehicle Driving) | (.63,16) | Spatial Orientation | (.51,16) |
| Mirror, Distance-in-Error (Vehicle Driving) | (.64,16) | | |
| Multidimensional Pursuit-Bank and Air Speed | (.31,6) | | |
| Multidimensional Pursuit-Bank and Altitude | (.32,6) | Rate Control | (.37,6) |

FACTOR: Response Orientation

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Multidimensional Pursuit-Banking and Heading | (.41,6)(.23,11) | | |
| Multidimensional Pursuit-Bank, Heading and Air Speed | (.33,6) | | |
| Power-off Stall (Flying) | (.43,14) | Kinesthetic Discrimination | (.61,14) |
| | | Multilimb Coordination | (.33,14) |
| Rectangular Pattern (Flying) | (.45,14) | Spatial Orientation | (.43,14) |
| Response Orientation Test (135°) | (.37,4) | Spatial Orientation | (.48,4) |
| Response Orientation Test (180°) | (.40,4) | Spatial Orientation | (.40,4) |
| Response Orientation Test (225°) | (.30,4) | Spatial Orientation | (.35,4) |

FACTOR: Response Orientation

| Identifying Test, Loadings, and References | Loading of This Test on Other Factors |
|---|---|
| Signal Discrimination (.52, 11) (Printed) | Perceptual Speed (.40, 11)<br>Spatial Orientation (.35, 11) |
| Signal Interpretation (.30, 18) | Spatial Orientation (.45, 18) |
| Slow-Flight Recovery (.41, 14) (Flying) | Multilimb Coordination (.36, 14)<br>Spatial Orientation (.47, 14) |
| Slow-Flight Turn (.41, 14) (Flying) | Control Precision (.31, 14)<br>Kinesthetic Discrimination (.30, 14)<br>Multilimb Coordination (.37, 14) |
| Straight and Level (.42, 14) (Flying) | Multilimb Coordination (.38, 14)<br>Rate Control (.41, 14) |
| Traffic Pattern at Auxiliary Field (.49, 14) (Flying) | Rate Control (.31, 14)<br>Spatial Orientation (.46, 14) |
| Traffic Pattern at Home Field (.48, 14) (Flying) | Multilimb Coordination (.43, 14)<br>Spatial Orientation (.46, 14) |
| Two Hand Matching (.61, 3) | |
| Unidimensional Matching (.61, 3) | |

FACTOR: Response Orientation

| Identifying Test, Loadings, and References | Loading of This Test on Other Factors |
|---|---|
| Visual Coincidence (.36, 6) | |

FACTOR: Single Integration/Differentiation Specific

Defined as : performance on the Single Differentiation/Integration (Mechanical) Test.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Analog Addition (Electronic) | (. 23, 17) | Movement Analysis | (. 22, 17) |
| | | Control Precision | (. 31, 17) |
| Rudder Control | (. 21, 17) | Movement Prediction | (. 23, 17) |
| | | Control Precision | (. 45, 2)(. 44, 6)(. 40, 11) (. 52, 17)(. 40, 18) |
| | | Multilimb Coordination | (. 48, 6)(. 36, 17) |
| Single Differentiation/ Integration (Mechanical) | (. 61, 17) | | |
| Time Sharing (Printed) | (. 21, 17) | Time Sharing | (. 71, 17) |

FACTOR: Spatial Orientation

Defined as : the ability to comprehend the arrangement of a visual stimulus pattern, primarily with respect to the subject's body as the frame of reference. Tests of this factor often ask: "What position am I in, if the situation looks like this (or vice versa)?"

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Aerial Orientation | (.61,4)(.52,18) | | |
| Complex Coordination | (.13,3)(.40,4)(.46,7)(.10,10)(.16,11)(.45,12)(.34,18) | Control Precision | (.36,2)(.45,3)(.35,6)(.44,7)(.47,10)(.50.11) |
| | | Multilimb Coordination | (.30,6)(.38,18) |
| | | Response Orientation | (.44,3)(.43,4)(.09,6)(.22,11)(.23,18) |
| | | Speed of Arm Movement | (.09,2)(.37,3)(.21,6)(.09,7)(.37,10)(.09,18) |
| Controls Orientation | (.46,11) | Visualization | (.36,11) |
| Coordinate Movements (Printed) | (36,11)(.36,18) | Integration | (.40,18) |
| | | Visualization | (.32,11)(.34,18) |
| Direction Control | (.34,4)(.39,11)(.24,18) | Response Orientation | (.58,4) |
| | | Visualization | (.44,11)(.34,18) |
| Directional Control | (.38,11)(.34,18) | Integration | (.30,18) |
| | | Visualization | (.34,11) |

**FACTOR:** Spatial Orientation

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Discrimination Reaction Time (Mechanical) | (.38,3)(.38,4)(.72,7) (.52,10)(.37,11)(.33,12) (.14,18) | Manual Dexterity | (.10,2)(.34,11)(.01,18) |
| | | Response Orientation | (.28,3)(.53,4)(.67,6) (.50,11)(.29,18) |
| | | Speed of Arm Movement | (.05,2)(.46,3)(.03,6) (-.03,7)(.25,10)(.07,18) |
| | | Visualization | (.16,3)(.23,10)(.10,11) (.34,18) |
| Drift Correction | (.40,11) | | |
| Forced Landing (Flying) | (.53,14) | Kinesthetic Discrimination | (.37,14) |
| | | Multilimb Coordination | (.49,14) |
| Formation Visualization | (.51,4) | | |
| Gliding Turn | (.38,14) | Kinesthetic Discrimination | (.46,14) |
| | | Multilimb Coordination | (.51,14) |
| Instrument Comprehension | (.49,3)(.69,4)(.50,7) (.46,10)(.37,12)(.47,18) | Mechanical Experience | (.19,3)(.41,7)(.16,10) (.16,18) |
| | | Perceptual Speed | (.29,3)(.15,7)(.35,10) (.15,18) |

FACTOR: Spatial Orientation

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| | | Verbal Comprehension | (.36,12)(.24,18) |
| | | Visualization | (.20,10)(.33,18) |
| Level-off from Climbing Turn (Flying) | (.52,14) | Kinesthetic Discrimination | (.32,14) |
| | | Multilimb Coordination | (.39,14) |
| Marking Accuracy | (.35,10)(.34,18) | Aiming | (.37,2)(.40,7) |
| | | Finger Dexterity | (.31,2)(.37,9)(.36,18) |
| | | Manual Dexterity | (.73,1)(.32,2)(.53,9)(.38,18) |
| Maze, Direction Changes (Vehicle Driving) | (.51,16) | Response Orientation | (.63,16) |
| $90^{o}$ Climbing Turn (Flying) | (.41,14) | Control Precision | (.68,14) |
| Non-Visual, Distance-in-Error (Vehicle Driving) | (.46,16) | Kinesthetic Discrimination | (.52,16) |
| Parallel Park Left, Direction Changes (Vehicle Driving) | (.62,16) | | |

**FACTOR:** Spatial Orientation

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Pattern Comprehension | (.31,3)(.40,4)(.33,10)<br>(.24,12) | Perceptual Speed | (.36,3)(.23,10) |
| | | Verbal Comprehension | (.46,12)(.16,18) |
| | | Visualization | (.60,3)(.55,4)(.60,10)<br>(.58,18) |
| Rate control | (.17,7)(.47,18) | Control Precision | (.30,6)(.01,7)(.24,11) |
| | | Rate Control | (.30,6)(.72,7)(.58,11) |
| Rectangular Pattern (Flying) | (.43,14) | Response Orientation | (.45,14) |
| Response Orientation Test (45°) | (.34,4) | Perceptual Speed | (.40,4) |
| Response Orientation Test (90°) | (.69,4) | | |
| Response Orientation Test(135°) | (.48,4) | Response Orientation | (.37,4) |
| Response Orientation Test (180°) | (.40,4) | Response Orientation | (.40,4) |
| Response Orientation Test (225°) | (.35,4) | Response Orientation | (.30,4) |

FACTOR: Spatial Orientation

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Response Orientation Test (270°) | (.30,4) | | |
| Rudder Control Stall (Flying) | (.31,14) | Control Precision | (.41,14) |
| | | Kinesthetic Discrimination | (.40,14) |
| Santa Ana Finger Dexterity | (.39,7)(-.07,11)(.20,12) | Aiming | (.17,7)(.33,15) |
| | | Finger Dexterity | (.16,2)(.42,7)(.46,12) (.06,15) |
| | | Manual Dexterity | (.47,2)(.38,11)(.28,15) |
| Signal Discrimination (Printed) | (.35,11) | Perceptual Speed | (.40,11) |
| | | Response Orientation | (.52,11) |
| Signal Interpretation | (.45,18) | Response Orientation | (.30,18) |
| Slow Flight Recovery (Flying) | (.47,14) | Multilimb Coordination | (.36,14) |
| | | Response Orientation | (.41,14) |
| Spatial Orientation | (.35,10)(.34,18) | Perceptual Speed | (.45,10)(.30,18) |
| Speed of Indentification | (.37,3)(.32,7)(.35,10) (.16,12) | Finger Dexterity | (.33,7)(.10,18) |
| | | Perceptual Speed | (.46,3)(.43,4)(.45,7) (.47,10)(.53,18) |

FACTOR: Spatial Orientation

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| | | Verbal Comprehension | (.37,12)(.20,18) |
| | | Visualization | (.38,3)(.29,10)(.06,18) |
| Stick and Rudder Orientation | (.53,18) | Visualization | (.57,18) |
| Straight and Level Gear Check (Flying) | (.47,14) | Rate Control | (.34,14) |
| Traffic Pattern at Auxiliary Field (Flying) | (.46,14) | Rate Control | (.31,14) |
| | | Response Orientation | (.49,14) |
| Traffic Pattern at Home Field (Flying) | (.39,14) | Multilimb Coordination | (.43,14) |
| | | Response Orientation | (.48,14) |
| Trailer Back Up (Vehicle Driving) | (.46,16) | | |
| Visual Pursuit | (.17,3)(.22,7)(.35,18) | Control Precision | (.24,3)(.36,7)(.20,10) |
| | | Perceptual Speed | (.46,3)(.28,7)(.50,10)(.35,18) |
| Visualization of Maneuvers | (.46,18) | Visualization | (.47,18) |

FACTOR: Speed of Arm Movement

Defined as : the speed with which a subject can make a discrete, gross arm movement. This factor is also called Rate of Movement.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Complex Coordination | (.09,2)(.37,3)(.21,6)(.09,7)(.37,10)(.09,18) | Control Precision | (.36,2)(45,3)(35,6)(.44,7)(.47,10)(.50,11) |
| | | Multilimb Coordination | (.30,6)(.38,18) |
| | | Response Orientation | (.44,3)(.43,4)(.09,6)(.22,11)(.23,18) |
| | | Spatial Orientation | (.13,3)(.40,4)(.46,7)(.39,10)(.16,11)(.45,12)(.34,18) |
| Discrimination Reaction Time (Mechanical) | (.05,2)(.46,3)(.03,6)(-.03,7)(.25,10)(.07,18) | Manual Dexterity | (.10,2)(.34,11)(.01,18) |
| | | Response Orientation | (.28,3)(.53,4)(.67,6)(.50,11)(.29,18) |
| | | Spatial Orientation | (.38,3)(.38,4)(.72,7)(.52,10)(.37,11)(.33,12)(.14,18) |
| | | Visualization | (.16,3)(.23,10)(.10,11)(.34,18) |
| Hand Precision Aiming (corrects) | (.14,2)(.56,9) | | |
| Hand Precision Aiming (errors) | (.01,2)(-.51,9) | | |

FACTOR: Speed of Arm Movement

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Jump Auditory Reaction Time | (.44,6)(.31,18) | Reaction Time | (.64,6)(.70,12)(.48,18) |
| Jump Visual Reaction Time | (19,2)(.54,6)(.65,3)(.40,7) (.54,10)(.36,18) | Reaction Time | (.73,2)(.54,6)(.73,12) (.52,18) |
| Large Tapping | (.21,2)(.31,9) | Wrist-Finger Speed | (.74,2)(.75,9) |
| Minnesota Rate of Manipulation-Placing | (.36,2)(.24,9)(-.13,18) | Aiming | (.34,9) |
| | | Finger Dexterity | (.31,2)(.37,9)(.36,18) |
| | | Manual Dexterity | (.73,1)(.32,2)(.53,9) (.38,18) |
| Plane Control | (.49,3) | Control Precision | (.38,3) |
| | | Multilimb Coordination | (.41,6) |
| Rate of Movement | (.42,3)(.40,7)(.48,12) | | |
| Rotary Aiming | (.46,2)(.38,6)(.53,7) (.02,18) | Aiming | (.22,9)(.38,15) |
| | | Wrist-Finger Speed | (.36,2) |
| Rotary Pursuit | (.22,2)(.47,3)(.17,6) (.20,7)(.34,10),(-.02,18) | Control Precision | (.26,3)(.49,7)(.60,18) |
| | | Manual Dexterity | (.17,2)(.35,11)(-.06,18) |

FACTOR: Speed of Arm Movement

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Ten Target Aiming (corrects) | (.66,2)(.72,9)(.50,18) | Aiming | (.31,9) |
| | | Manual Dexterity | (.05,2)(.42,18) |
| Ten Target Aiming (errors) | (-.35,2)(-.70,9)(.63,18) | Manual Dexterity | (.43,2)(.35,18) |
| Two Plate Tapping | (.54,2)(-.05,18) | Control Precision | (.41,18) |
| | | Manual Dexterity | (.24,2)(.35,18) |
| | | Wrist-Finger Speed | (.36,2) |

FACTOR: Speed of Limb Movement

Defined as : the speed with which an individual can make rapid ballistic or adjustive movements of arms or legs, when accuracy and force requirements are not involved.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Arm Circling | (.39,8) | Explosive Strength | (.52,8) |
| Ball Balance | (.47,8) | | |
| Plate Tapping | (.44,8) | Explosive Strength | (.39,8) |
| Two Foot Lengthwise Balance - Eyes Closed | (.33,8) | | |
| Two Foot Lengthwise Balance - Eyes Open | (.31,8) | | |
| Two Foot Tapping | (.46,8) | | |

FACTOR: Static Strength

Defined as : the ability to exert a maximum force for a brief period of time where the force is exerted continuously up to this maximum. In contrast to Dynamic Strength, the force exerted is against external objects rather than in supporting or propelling the body's own weight.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Arm Pull - Dynamometer | (.71,8) | | |
| Hand Grip | (.72,8) | | |
| Height | (.42,8) | Athletic Experience Specific | (.32,8) |
| | | Dynamic Strength | (-.39,8) |
| | | Trunk Strength | (-.31,8) |
| Medicine Ball Put-Sitting | (.44,8) | | |
| Medicine Ball Put-Standing | (.71,8) | | |
| Pull Weights-Arms (in 20 seconds) | (.33,8) | Weight Balance | (.50,8) |
| Push Weights - Arms (in 20 seconds) | (.51,8) | Dynamic Strength | (.38,8) |
| | | Weight Balance | (.44,8) |
| Push Weights - Feet (in 20 seconds) | (.35,8) | Weight Balance | (.43,8) |

FACTOR: Static Strength

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Softball Throw | (.32, 8) | Explosive Strength | (.54, 8) |
| Trunk Pull-Dynamometer | (.59, 8) | | |
| Weight | (.70, 8) | Dynamic Strength | (-.43, 8) |

FACTOR: Time Sharing

Defined as : the ability to obtain and utilize information presented within more than a single visual display.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Time Sharing (Mechanical) | (.79, 17) | Control Precision | (.26, 17) |
| Time Sharing (Printed) | (.71, 17) | Single Integration/ Differentiation Specific | (.21, 17) |

FACTOR: Trunk Flexibility (Tentative)

Defined as : the ability of the trunk muscles to endure strain and distortion.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Backing down Wall | (. 50, 15) | Leg Flexibility | (. 33, 15) |
| Table Vault | (. 37, 15) | Explosive Strength | (. 34, 15) |
| | | Jump Performance | (. 32, 15) |

FACTOR: Trunk Strength

Defined as : the strength of trunk muscles, and particularly the abdominal muscles.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Abdominal Pivot | (. 64, 15) | | |
| Height | (-. 31, 8) | Athletic Experience Specific | (. 32, 8) |
| | | Dynamic Strength | (-. 39, 8) |
| | | Static Strength | (. 42, 8) |
| Hold Half Sit-up | (. 45, 8) | Dynamic Strength | (. 30, 8) |
| Leg Lifts (in 20 seconds) | (. 47, 8) | Dynamic Strength | (. 32, 8) |
| Leg Raiser | (. 43, 8)(. 43, 15) | Dynamic Strength | (. 35, 8) |
| Push-ups (to limit) | (. 43, 15) | Dynamic Strength | (. 74, 8) |
| | | Limb Strength | (. 59, 15) |

FACTOR: Verbal Comprehension

Defined as : knowledge and understanding of the English language.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Background for Current Affairs | (.77,12)(.67,18) | | |
| General Mechanics | (.44,12) | Mechanical Experience | (.64,3)(.81,7)(.62,10) (.47,18) |
| | | Visualization | (.09,3)(.06,10)(.38,18) |
| Instrument Comprehension | (.36,12)(.24,18) | Mechanical Experience | (.19,3)(.41,7)(.16,10) (.16,18) |
| | | Perceptual Speed | (.29,3)(.15,7)(.35,10) (.15,18) |
| | | Spatial Orientation | (.49,3)(.69,4)(.50,7) (.46,10)(.37,12)(.47,18) |
| | | Visualization | (.20,10)(.33,18) |
| Mechanical Principles | (.43,12) | Mechanical Experience | (.61,3)(.49,10) |
| | | Visualization | (.40,3)(.41,4)(.41,10) |
| Pattern Comprehension | (.46,12)(.16,18) | Perceptual Speed | (.36,3)(.23,10) |
| | | Spatial Orientation | (.31,3)(.40,4)(.33,10) (.24,12) |
| | | Visualization | (.60,3)(.55,4)(.60,10) (.58,18) |

FACTOR: Verbal Comprehension

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Speed of Identification | (.37, 12)(.20, 18) | Finger Dexterity | (.33, 7)(.10, 18) |
| | | Perceptual Speed | (.46, 3)(.43, 4)(.45, 7) (.47, 10)(.53, 18) |
| | | Spatial Orientation | (.37, 3)(.32, 7)(.35, 10) (.16, 12) |
| | | Visualization | (.38, 3)(.29, 10)(.06, 18) |
| Word Knowledge (Vocabulary) | (.78, 12)(.67, 18) | | |

FACTOR: Visual Feedback (Tentative)

Defined as : the ability to use fine visual cues in the manipulation and placing of small objects.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Bowling Green Tweezer Dexterity | (.53,1) | Manual Dexterity | (.37,1) |
| Depth Perception | (.34,1) | Visual Sensitivity | (.53,1) |
| Dowel Manipulation | (.33,1) | Manual Dexterity | (.60,1)(.40,15) |
| O'Connor Finger Dexterity | (.43,1) | Finger Dexterity | (.53,2)(.59,9)(.49,18) |
| | | Manual Dexterity | (.50,1)(.25,2) |
| O'Connor Tweezer Dexterity | (.42,1) | | |
| Orthorater, Near Acuity-Left Eye | (.40,1) | Visual Sensitivity | (.62,1) |
| Orthorater, Near Acuity-Right Eye | (.36,1) | Visual Sensitivity | (.65,1) |
| Pin Moving | (.31,1) | Manual Dexterity | (.32,1) |

FACTOR: Visual Sensitivity

Defined as : the ability to make fine visual discriminations involving acuity and/or depth perception.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Depth Perception | (.53, 1) | Visual Feedback | (.34, 1) |
| Orthorater, Depth Perception | (.57, 1) | | |
| Orthorater, Near Acuity - Left Eye | (.62, 1) | Visual Feedback | (.40, 1) |
| Orthorater, Near Acuity - Right Eye | (.65, 1) | Visual Feedback | (.36, 1) |

FACTOR: Visualization

Defined as : the ability to mentally manipulate visual images.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Complex Movements | (.32,11)(.34,18) | Integration | (.30,18) |
| Controls Orientation | (.36,11) | Spatial Orientation | (.46,11) |
| Direction Control | (.44,11)(.34,18) | Spatial Orientation | (.34,4)(.39,11)(.24,18) |
| | | Response Orientation | (.58,4) |
| Directional Control (Printed) | (.34,11) | Integration | (.30,18) |
| | | Spatial Orientation | (.38,11)(.34,18) |
| Discrimination Reaction Time (Mechanical) | (.16,3)(.23,10)(.10,11) (.34,18) | Manual Dexterity | (.10,2)(.34,11)(.01,18) |
| | | Response Orientation | (.28,3)(.53,4)(.67,6) (.50,11)(.29,18) |
| | | Spatial Orientation | (.38,3)(.38,4)(.72,7) (.52,10)(.37,11)(.33,12) (.14,18) |
| | | Speed of Arm Movement | (.05,2)(.46,3)(.03,6) (-.03,7)(.25,10)(.07,18) |
| Formation Visualization | (.58,4)(.61,18) | | |

FACTOR: Visualization

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| General Mechanics | (.09, 3)(.06, 10)(.38, 18) | Mechanical Experience | (.64, 3)(.81, 7)(.62, 10)<br>(.47, 18) |
| | | Verbal Comprehension | (.44, 12) |
| Instrument Comprehension | (.20, 10)(.33, 18) | Mechanical Experience | (.19, 3)(.41, 7)(.16, 10)<br>(.16, 18) |
| | | Perceptual Speed | (.29, 3)(.15, 7)(.35, 10)<br>(.15, 18) |
| | | Spatial Orientation | (.49, 3)(.69, 4)(.50, 7)<br>(.46, 10)(.37, 12)(.47, 18) |
| | | Verbal Comprehension | (.36, 12)(.24, 18) |
| Mechanical Comprehension | (.38, 18) | Mechanical Experience | (.47, 18) |
| Mechanical Principles | (.40, 3)(.41, 4)(.41, 10) | Mechanical Experience | (.61, 3)(.49, 10) |
| | | Verbal Comprehension | (.43, 12) |
| Pattern Comprehension | (.60, 3)(.55, 4)(.60, 10)<br>(.58, 18) | Perceptual Speed | (.36, 3)(.23, 10) |
| | | Spatial Orientation | (.31, 3)(.40, 4)(.33, 10)<br>(.24, 12) |
| | | Verbal Comprehension | (.46, 12)(.16, 18) |
| Spatial Visualization | (.73, 4) | Perceptual Speed | (.35, 4) |

**FACTOR:** Visualization

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Speed of Identification | (.38, 3)(.29, 10)(.06, 18) | Finger Dexterity | (.33, 7)(.10, 18) |
| | | Perceptual Speed | (.46, 3)(.43, 4)(.45, 7) (.47, 10)(.53, 18) |
| | | Spatial Orientation | (.37, 3)(.32, 7)(.35, 10) (.16, 12) |
| | | Verbal Comprehension | (.37, 12)(.20, 18) |
| Stick and Rudder Orientation | (.57, 18) | Spatial Orientation | (.53, 18) |
| Visualization of Maneuvers | (.47, 18) | Spatial Orientation | (.46, 18) |

FACTOR: Weight Balance (Tentative)

Defined as : the ability to balance weights properly. It is unlikely that this factor represents an important strength factor.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Pull Weights - Arms (in 20 seconds) | (. 50, 8) | Static Strength | (. 33, 8) |
| Push Weights - Arms (in 20 seconds) | (. 44, 8) | Dynamic Strength | (. 38, 8) |
| | | Static Strength | (. 51, 8) |
| Push Weights - Feet (in 20 seconds) | (. 43, 8) | Static Strength | (. 35, 8) |

FACTOR: Wrist-Finger Speed

Defined as : the ability to make rapid pendular and/or rotary wrist movements, best measured by printed tests involving rapid, repetitive jabbing movements with a pencil, where accuracy is not critical. This ability does not involve eye-hand coordination nor does it apply to many apparatus tests.

| Identifying Test, Loadings, and References | | Loading of This Test on Other Factors | |
|---|---|---|---|
| Aiming | (.45,2)(.52,9) | Aiming | (.63,2)(.36,7)(.57,9) |
| | | Finger Dexterity | (.12,2)(.35,7)(.30,9) |
| Discrimination Reaction Time (Printed) | (.14,2)(.30,9) | Manual Dexterity | (.26,2)(.34,9)(.04,11) (.15,18) |
| | | Perceptual Speed | (.35,10)(.14,18) |
| | | Response Orientation | (.42,4)(.52,6)(.41,11) (.38,18) |
| Large Tapping | (.74,2)(.75,9) | Speed of Arm Movement | (.21,2)(.31,9) |
| Medium Tapping | (.74,2)(.77,9) | | |
| Pursuit Aiming I | (.50,2)(.52,9) | Aiming | (.68,2)(.63,9) |
| Pursuit Aiming II | (.48,2)(.54,9) | Aiming | (.63,2)(.63,9) |
| Rotary Aiming | (.36,2) | Aiming | (.22,9)(.38,15) |
| | | Speed of Arm Movement | (.46,2)(.38,6)(.53,7) (.02,18) |
| Square Marking | (.29,2)(.46,9) | Aiming | (.30,2)(.31,9)(.71,15) |

FACTOR: Wrist-Finger Speed

| Identifying Test, Loadings, and References | Loading of This Test on Other Factors | |
|---|---|---|
| Two Plate Tapping (.36, 2) | Control Precision | (.41, 18) |
| | Manual Dexterity | (.24, 2)(.35, 18) |
| | Speed of Arm Movement | (.54, 2)(-.05, 18) |

# APPENDIX A

## REFERENCES

In the conduct of the survey of the technical literature, several hundred documents were studied. The reference list presented here is restricted to those studies which bore directly upon the selection of the tests included in the test console. It should be noted that the majority of these studies are from the program of Fleishman and associates which has been concerned with the development of methodology for classifying perceptual-motor tasks in terms of the common abilities required to perform them.


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15. Hempel, W. E. & Fleishman, E. A. A factor analysis of physical proficiency and manipulative skill. Skill Components Research Laboratory, Lackland AFB, Texas, Research Bulletin, Report AFPTRC-TR-54-34, 1954 , also in J. appl. Psychol., 1955, 39, 12-16.

16. Herbert, M. J. Analysis of a complex skill: vehicle driving. Human Factors, 1963, 5, 363-372.

17. Parker, J. F. Use of an engineering analogy in the development of tests to predict tracking performance. The Matrix Corporation under Office of Naval Research Contract Nonr-3065(00), 1964.

18. Parker, J. F. & Fleishman, E. A. Ability factors and component performance measures as predictors of complex tracking behavior. Psychol. Monogr., 1960, 74, 1-36.

The following studies, while not cited in the identification of specific ability factors, bear directly upon this area and are worthy if inclusion here.

19. Fleishman, E. A. Psychomotor tests in drug research. In Miller, J. G. and Uhr, L. (Eds.) Drugs and Behavior. New York: Wiley, 1960.

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# APPENDIX B

## TASK ANALYSIS OF GEMINI MISSION

In order to gain insight into the types of performance required in space flight, a task analysis of the Gemini mission was performed. Tasks required for a Gemini mission were considered to be representative of those which will be required for an Apollo mission or a Manned Orbital Laboratory mission.

The decision to study a Gemini mission was based upon two practical considerations. First, in view of the current dynamic status of the Apollo and MOL programs, it seemed advisable to limit our study to the "firm" Gemini mission. Second, although tentative (but general) Apollo flight plans are available, they are classified. Since it is hoped that the end product of this endeavor will be of use not only to NASA, but also to other segments of the research community, the decision was made to avoid security classification problems by restricting our task analysis to the unclassified Project Gemini.

Duties and tasks to be performed during a Gemini rendezvous mission were analyzed from the point of view of perceptual-motor performance. The result is not a task analysis in the usual sense of the term, but, more correctly, an analysis of perceptual-motor tasks. This analysis should not be considered comprehensive in areas other than perceptual-motor performance.

The task analysis is, to the extent possible, sequential over time. It lists only duties to be performed by the Command Astronaut. Mission segments comply with those described in the Gemini Spacecraft Crew Station System Specification. The first column lists duties. Duties are meaningful groupings of tasks. The duty, "Perform guidance and control", requires a number of specific tasks.

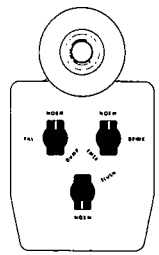
The Task column lists perceptual-motor tasks outlined in the Gemini Spacecraft Crew Station System Specification. While the emphasis in this analysis is on perceptual-motor tasks, some tasks, although not primarily of a perceptual-motor nature, are included to retain the continuity of the overall mission. These tasks are of the "listen for", "watch for", "verify", "monitor", and "report" type.

The column titled Response Element lists only perceptual-motor responses--specific behavioral responses involved in the manipulation of equipment on the Gemini spacecraft. Although listening, verifying, etc. are clearly responses, they are not included because of their limited perceptual-motor nature. As

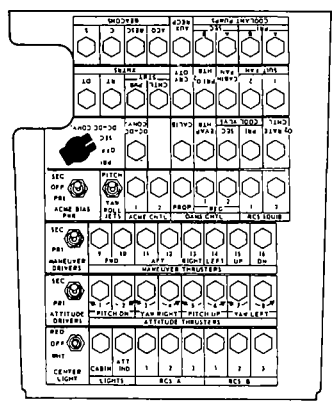
can be seen, the very complex Gemini mission can be described in terms of a finite number of response elements.

The final column lists instrument or control location within the spacecraft. The Gemini control panel is presented next to show the location of instruments and controls involved in tasks. The abbreviations refer to the overhead, left, and right switch/circuit breaker panels (OS/CB, LS/CB, RS/CB panels), and the Command Astronauts Panel (CA Panel).

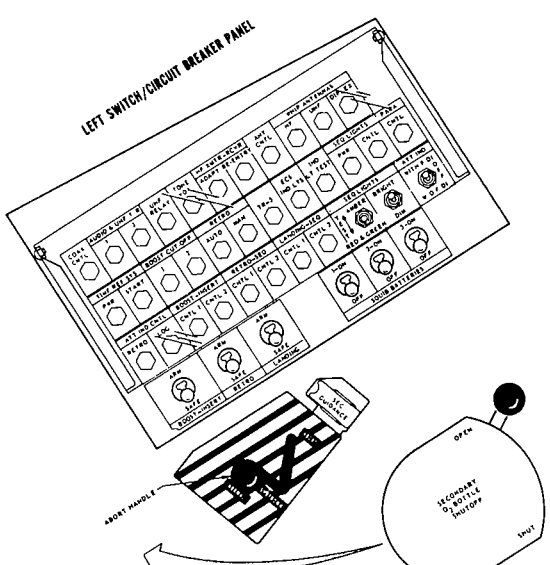
WATER MANAGEMENT PANEL



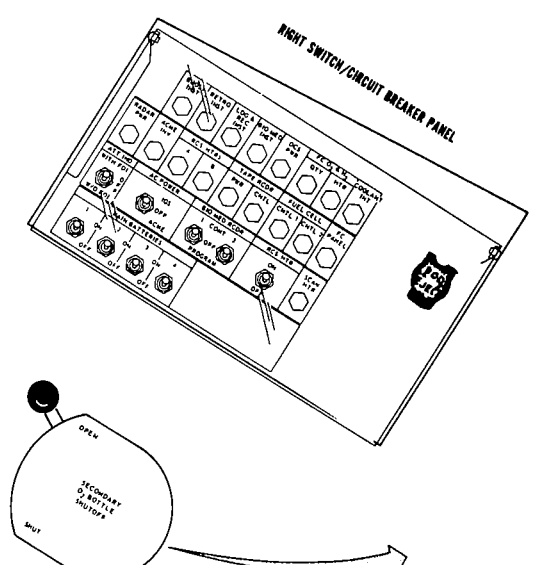
OVERHEAD SWITCH/CIRCUIT BREAKER PANEL



LEFT SWITCH/CIRCUIT BREAKER PANEL




RIGHT SWITCH/CIRCUIT BREAKER PANEL



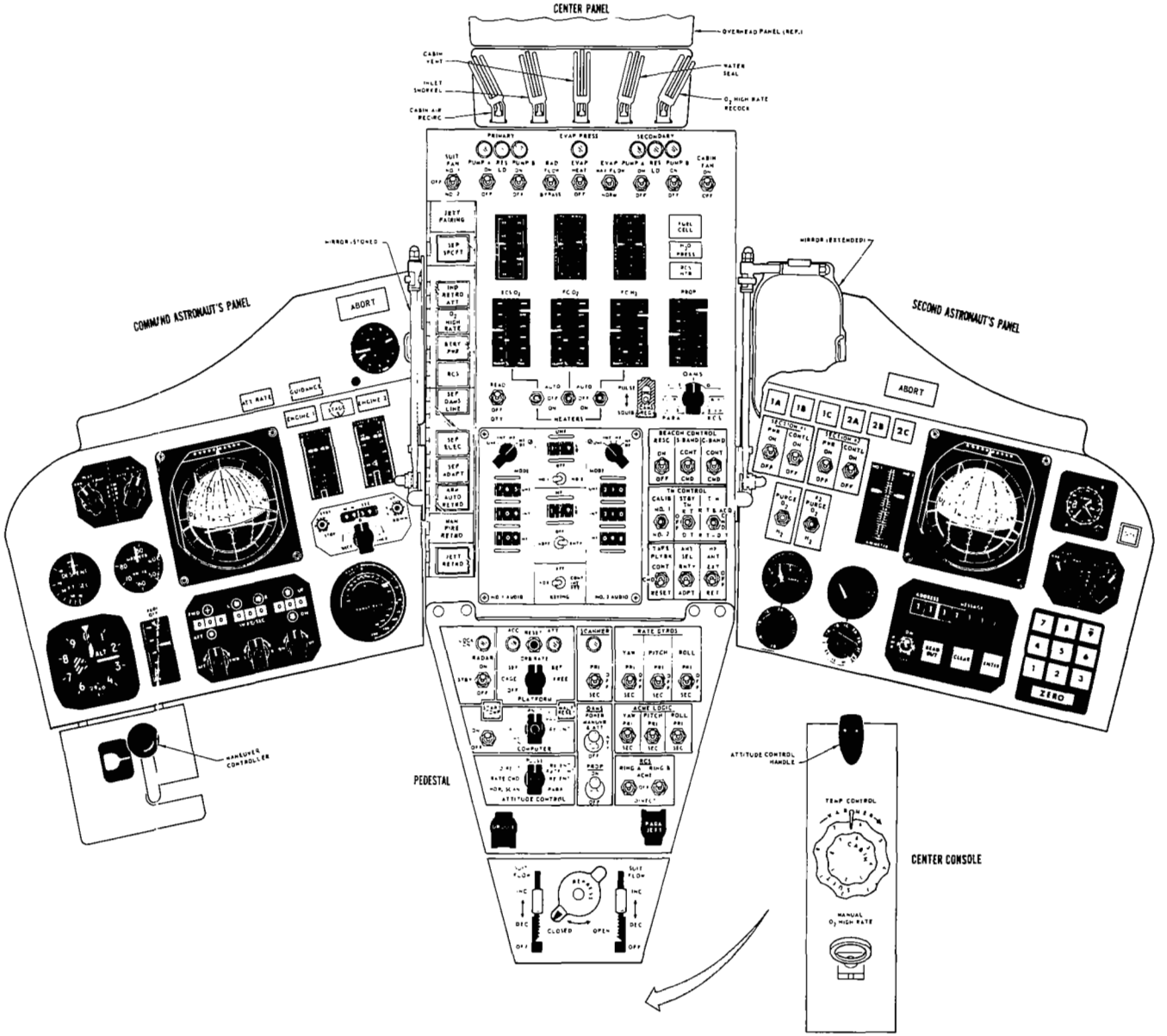



Figure 4. Gemini Control Panel.

# GEMINI TASK ANALYSIS

Mission Segment: Pre-launch

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Prepare for pre-launch checkout | Set audio mode to UHF | Position detented rotary switch | Center panel |
| | Set voice communication on #2 UHF and verify | Set toggle switch | Center panel |
| | Set audio mode to Intercom | Position detented rotary switch | Center panel |
| | Verify operation of intercom | | |
| | Set audio mode to UHF | Position detented rotary switch | Center panel |
| | Set and verify audio communication on #1 UHF | Set toggle switch | Center panel |
| | Close and lock hatch | Manipulate lever | |
| | Select Suit Fan #1 and verify operation | Set toggle switch | Center panel |
| | Select Suit Fan on #2 and verify operation | Set toggle switch | Center panel |
| | Return to Suit Fan # 1 | Set toggle switch | Center panel |
| | Set suit and cabin temperature to full cold prior to lift off and verify | Position continuous rotary switch | Center console |

Mission Segment: Pre-launch

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform pre-launch checkout | Check and report circuit breaker positions for launch | | |
| | Check and verify sequence switch lights are off | | |
| | Set event timer power to Standby | Set toggle switch | CA panel |
| | Check event timer operation | Set toggle switch, position continuous rotary switch | CA panel |
| | Set event timer readout to Zero | Position continuous rotary switch | CA panel |
| | Verify and report computer set to On | | |
| | Verify and report computer set to Pre-launch | | |
| | Verify and report ACME logic set to Primary | | |
| | Verify and report ACME bias power set to Primary | | |
| | Verify and report DC-DC converter set to Normal | | |
| | Set platform to Align | Position detented rotary switch | Pedestal |
| | Set attitude indicator to With FDI | Set toggle switch | LS/CB panel |

# GEMINI TASK ANALYSIS

Mission Segment: Pre-launch

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform pre-launch checkout (con'd) | Monitor and report attitude readings as required | | |
| | Report display readings as requested | | |
| | Set radar to Off and report | Set toggle switch | Pedestal |
| | Set platform to Free and report | Position detented rotary switch | Pedestal |
| | Set scanner to On and report | Set toggle switch | Pedestal |
| | Set rate gyros to Primary and report | Set toggle switch | Pedestal |
| | Set computer to On and report | Set toggle switch | Pedestal |
| | Set computer to Ascent and report | Position detented rotary switch | Pedestal |
| | Set attitude control to Rate Command and report | Position detented rotary switch | Pedestal |
| | Set OAMS prop to Off and report | Set lever-lock toggle switch | Pedestal |
| | Set OAMS power to Maneuver and Attitude and report | Set lever-lock toggle switch | Pedestal |
| | Set RCS (Ring A & B) to Off and report | Set toggle switch | Pedestal |
| | Set flight director reference (FDR) to Computer and report | Position detented rotary switch | CA panel |

Mission Segment: Pre-launch

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform pre-launch checkout (cont'd) | Set flight director mode (FDM) to Rate and report | Position detented rotary switch | CA panel |
| | Set attitude drivers to Primary and report | Set toggle switch | OS/CB panel |
| | Set maneuver drivers to Primary and report | Set toggle switch | OS/CB panel |
| Prepare for launch | Check that ejection seat time delay initiator is connected | | |
| | Check that ejection handle is stowed and safetied | | |
| | Check egress $0_2$ pressure | | |
| | Assume proper position in seat | | |
| | Secure body and arm restraints | Fasten harness buckles | |
| | Check inertia reel operation and lock | Set locking device | |
| | Arm seat for ejection | Set ejection handle, remove ejection seat safety | |
| | Set squib batteries to On | Set toggle switch | RS/CB panel |
| | Set boost insertion squib bus to Armed | Set lever-lock toggle switch | LS/CB panel |
| | Monitor all displays and verify ready for launch | | |

# GEMINI TASK ANALYSIS

Mission Segment: Launch

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Monitor launch events | Monitor first and second stage displays | | |
| | Monitor first and second stage warning lights | | |
| | Monitor first and second stage acceleration | | |
| | Monitor time sequence for first and second stage events | | |
| | Monitor time for first stage fuel and oxidizer tank pressure profile | | |
| | Monitor attitude rate | | |
| | Report systems and personal status | | |
| | Monitor approach to first stage cutoff | | |
| | Monitor time for abort mode change | | |
| | Confirm abort mode change with second astronaut | | |

Mission Segment: Launch

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform emergency activities as required | Actuate spacecraft launch guidance in the event of booster guidance failure | Set toggle switch | Abort handle |
| | Eject by pulling abort handle in the event of abort below 70,000 feet | Manipulate abort handle | Abort handle |
| | Set abort handle to Shutdown in event of abort above 70,000 feet | Manipulate abort handle | Abort handle |
| | Set abort handle to Abort | Manipulate abort handle | Abort handle |
| | Report booster shutdown and separation | | |
| | Perform normal landing procedure | (See Retrograde, Re-entry and Landing Mission Segments for description of normal landing procedures) | |

# GEMINI TASK ANALYSIS

Mission Segment: Staging

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Monitor and report staging events | Monitor and verify illumination of stage light | | |
| | Monitor and verify second stage ignition | | |
| | Monitor second stage attitude rate lights | | |
| | Monitor second stage warning lights | | |
| | Monitor second stage displays | | |
| | Monitor timing of second stage events | | |
| Perform staging activities | Press Jettison Fairing switch | Depress push button switch | Center panel |
| | Report first stage separation | | |
| | Report systems and personal status | | |
| | Report second stage cutoff | | |
| Perform emergency activities as required | Actuate spacecraft launch guidance in the event of booster guidance failure | Set toggle switch | Abort handle |

Mission Segment: Staging

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform emergency activities as required (cont'd) | In the event of abort above 20,000 ft/sec velocity prior to space craft separation: | | |
| | Set abort handle to Shutdown | Manipulate abort handle | Abort handle |
| | Actuate Spacecraft Separate switch-light | Depress push button switch | Center panel |
| | Set OAMS prop to On | Set lever-lock toggle switch | Pedestal |
| | Maneuver clear of launch vehicle | Manipulate maneuver controller | CA panel |
| | Assume retro attitude | Manipulate attitude controller | Center console |
| | Coordinate retrofire information with ground | | |
| | Perform normal landing | (See Retrograde, Re-entry and Landing Mission Segments for description of normal landing procedures) | |

# GEMINI TASK ANALYSIS

Mission Segment: Insertion

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Monitor separation | Monitor IVI | | |
| | Monitor time of spacecraft separation | | |
| | Depress Spacecraft Separation 20 seconds after SECO | Depress push button switch | Center panel |
| | Report separation | | |
| | Report system and personal status | | |
| Establish orbit | Set OAMS prop to On | Set lever-lock toggle switch | Pedestal |
| | Set booster-insertion squib bus to Safe | Set lever-lock toggle switch | LS/CB panel |
| | Fire forward maneuver thrusters to effect physical separation | Manipulate maneuver controller | Center console |
| | Make further insertion corrections | Manipulate maneuver controller and attitude controller | Center console; CA panel |
| | In response to ground instructions: | | |
| | Align platform in preparation for rendezvous | Position detented rotary switch | Pedestal |

# GEMINI TASK ANALYSIS

Mission Segment: Insertion

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Establish orbit (cont'd) | or | | |
| | Set platform to Off | Position detented rotary switch | Pedestal |
| | Set computer to Off | Set toggle switch | Pedestal |
| | Control attitude by horizon scanner | Manipulate attitude controller | Center console |
| | Verify orbit | | |
| Perform emergency activities as required | Coordinate retrofire information with ground to land normally in case of Mission Abort | | |
| | Perform normal landing | (see Retrograde, Re-entry and Landing) | |
| | Perform retro and re-entry procedures immediately in case of Emergency Abort | (see Retrograde, Re-entry and Landing) | |

# GEMINI TASK ANALYSIS

Mission Segment: Rendezvous (Catch-up)

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Program timing cycle | Set event timer as required for timed rendezvous functions | Position detented rotary switch | CA panel |
| | Start event timer as required | Set toggle switch | CA panel |
| | Monitor event timer as required | | |
| Monitor report and adjust sub-systems as required | Report applicable systems and personal status | | |
| | Adjust audio squelch as required | Position continuous rotary switch | Center panel |
| | Set transmitter to Real Time-Delay Time (TM/RT-DT) over ground stations without command capability | Set toggle switch | Center panel |
| | Select UHF, HF as required depending upon spacecraft orbital location | Position detented rotary switch | Center panel |
| | Operate suit flow valve to adjust $0_2$ flow as required | Position detented slide control | Pedestal |
| | Monitor and report ECS displays as requested during Second Astronauts sleep period | | |

# GEMINI TASK ANALYSIS

Mission Segment: Rendezvous (Catch-up)

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Monitor report and adjust sub-systems as required (cont'd) | Select and hold instrumentation calibrate # 1 and # 2 once every hour during second Astronauts sleep period | Set toggle switch | Center panel |
| Perform guid-ance and con-trol | Set squib batteries to Off | Set toggle switches | RS/CB panel |
| | Receive and verify rendezvous instructions and parameters | | |
| | either | | |
| | Set computer to Catch-up | Position detented rotary switch | Pedestal |
| | Control spacecraft to small end forward (SEF) | Manipulate attitude controller | Center console |
| | Null FDIs | Manipulate attitude controller with FDI reference | Center console; CA panel reference |
| | Listen for ground command to initiate radar search | | |
| | or | | |
| | Set platform rate gyros to Off | Set toggle switch | Pedestal |
| | Set computer to Off | Set toggle switch | Pedestal |

Mission Segment: Rendezvous (Catch-up)

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform guidance and control (cont'd) | Control attitude using rate mode and horizon scanner | Manipulate attitude controller | Center console |
| | Wait for and receive ground command to align platform | | |
| | Set platform to Cage | Position detented rotary switch | Pedestal |
| | Set attitude control to Pulse-Direct or Rate Command mode | Position detented rotary switch | Pedestal |
| | Control to SEF orientation | Manipulate attitude controller | Center console |
| | Maintain FDI near null in all three axes | Manipulate attitude controller | Center console |
| | Set platform to SEF | Position detented rotary switch | Pedestal |
| | Set attitude control to Pulse | Position detented rotary switch | Pedestal |
| | Set FDM to Mix | Position detented rotary switch | CA panel |
| | Set FDR to Platform | Position detented rotary switch | CA panel |
| | Control attitudes to null FDIs | Manipulate attitude controller with FDI reference | Center console, CA panel reference |
| | Set computer to On | Set toggle switch | Pedestal |
| | Set computer to Catch-up | Position detented rotary switch | Pedestal |

Mission Segment: Rendezvous (Catch-up)

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform guidance and control (cont'd) | Listen for ground command to initiate radar search | | |
| | Set UHF antenna to Adapter when radar is energized | Set toggle switch | Center panel |
| Perform escape activities as required | Tasks required for these duties are the same as those required for escape activities of Insertion Mission Segment | | |

# GEMINI TASK ANALYSIS

Mission Segment: Rendezvous (Midcourse)

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Program timing cycle<br>Monitor, report and adjust subsystems as required | Tasks required for these duties are the same as those required for the same duties in Rendezvous (Catch-up) | | |
| Perform guidance and control | Receive and verify radar tracking information | | |
| | Report radar and visual acquisition of target | | |
| | Set radar to Standby | Set toggle switch | Pedestal |
| | Set radar to On after one minute warmup | Set toggle switch | Pedestal |
| | Set platform to Orbit Rate | Position detented rotary switch | Pedestal |
| | Set attitude control to Rate Command | Position detented rotary switch | Pedestal |
| | Roll spacecraft 360$^{o}$ to insure unambiguous radar lock-on when radar lock-on light turns green | Manipulate attitude controller | Center console |
| | Set attitude control to Pulse | Position detented rotary switch | Pedestal |

Mission Segment: Rendezvous (Midcourse)

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform guidance and control (cont'd) | Set FDR to Radar | Position detented rotary switch | CA panel |
| | Control attitude to null FDIs | Manipulate attitude controller | Center console |
| | Set computer to Rendezvous | Position detented rotary switch | Pedestal |
| | Set event timer to 7 min., 0 sec. | Position detented rotary switch | CA panel |
| | Maintain attitude | Manipulate attitude controller | Center console |
| | Watch for first $\Delta V_T$ on IVI | | |
| | Choose satisfactory $\Delta V_T$ | | |
| | Depress Start Computer button | Depress push button switch | Pedestal |
| | Set FDR to Computer | Position detented rotary switch | CA panel |
| | Set attitude control to Rate Command | Position detented rotary switch | Pedestal |
| | Maintain attitude | Manipulate attitude controller | Center console |
| | Thrust $\Delta V_T$ to zero when computer light turns green | Manipulate maneuver controller | CA panel |
| | Null FDIs | Manipulate attitude controller | Center console |
| | Maintain nulled FDIs | Manipulate attitude controller | Center console |
| | Watch for computer light to go Off | | |

Mission Segment: Rendezvous (Midcourse)

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform guidance and control (cont'd) | Set event timer to Up after computer light has gone off | Set toggle switch | CA panel |
| | Set attitude control to Rate Command | Position detented rotary switch | Pedestal |
| | Set FDR to Computer | Position detented rotary switch | CA panel |
| | Control attitude to null FDIs | Manipulate attitude controller | Center console |
| | Set platform to SEF | Position detented rotary switch | Pedestal |
| | Set attitude control to Pulse | Position detented rotary switch | Pedestal |
| | Watch for start computer light to come on | | |
| | Set attitude control to Rate Command after computer light comes on | Position detented rotary switch | Pedestal |
| | Set platform to Orbit Rate | Position detented rotary switch | Pedestal |
| | Set FDR to Radar | Position detented rotary switch | CA panel |
| | Control attitude to null FDIs | Manipulate attitude controller | Center console |
| | Watch for appearance of $\Delta V$ on IVI | | |
| | Thrust as required to zero $\Delta V$ 15 min. 00 sec. after $T_o$ ($T_o$ is midpoint time of initial thrust) | Manipulate maneuver controller | CA panel |

Mission Segment: Rendezvous (Midcourse)

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform guidance and control (cont'd) | Set attitude control to Pulse | Position detented rotary switch | Pedestal |
| | Control attitude | Manipulate attitude controller | Center console |
| | Watch for computer light to go Off<br><br>22 min. 00 sec. after $T_o$: | | |
| | Set attitude control to Rate Command | Position detented rotary switch | Pedestal |
| | Set FDR to Computer | Position detented rotary switch | CA panel |
| | Control attitude | Manipulate attitude controller | Center console |
| | Set platform to SEF | Position detented rotary switch | Pedestal |
| | Set attitude control to Pulse | Position detented rotary switch | Pedestal |
| | Control attitude | Manipulate attitude controller | Center console |
| | Watch for appearance of computer light<br><br>28 min. 40 sec. after $T_o$: | | |
| | Set attitude control to Rate Command | Position detented rotary switch | Pedestal |
| | Set platform to Orbit Rate | Position detented rotary switch | Pedestal |

# GEMINI TASK ANALYSIS

Mission Segment: Rendezvous (Midcourse)

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform guidance and control (cont'd) | Control attitude | Manipulate attitude controller | Center console |
| | Set FDR to Radar | Position detented rotary switch | Pedestal |
| | Control attitude | Manipulate attitude controller | Center console |
| | Watch for $\Delta V_T$ | | |
| | 30 min. 00 sec. after $T_o$: | | |
| | Repeat thrust procedure of 15 min. 00 sec. | | |
| | 37 min. 00 sec. after $T_o$: | | |
| | Repeat platform align procedure of 22 min. 00 sec. | | |
| | 43 min. 40 sec. after $T_o$: | | |
| | Repeat reestablish radar lock-on procedure of 28 min. 40 sec. | | |
| | 45 min. 00 sec. after $T_o$: | | |
| | Repeat thrust procedure | | |

Mission Segment: Rendezvous (Midcourse)

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform guidance and control (cont'd) | 52 min. 00 sec. after $T_o$: | | |
| | Repeat platform align procedure | | |
| | 58 min. 40 sec. after $T_o$: | | |
| | Repeat reestablish radar lock-on procedure | | |
| | 60 min. 00 sec. after $T_o$: | | |
| | Repeat thrust procedure | | |
| | (This completes the closed loop maneuvers. The following method using only range and range rate displays is semi-optional) | | |
| | Proceed as above until immediately before start computer button is depressed | | |
| | Apply pitch and yaw thrust as required to arrest the apparent motion of the target in the visible star background | Manipulate attitude controller | Center console |

# GEMINI TASK ANALYSIS

Mission Segment: Rendezvous (Midcourse)

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform guidance and control (cont'd) | Apply roll thrust pulses to align either the vertical or lateral maneuvering thrusters to the direction of apparent star motion while doing above. | Manipulate attitude controller | Center console |
| | Apply translational thrust with the aligned maneuvering thrusters until star motion has been stopped | Manipulate maneuver controller | CA panel |
| | Monitor closing rate while doing above | | |
| | Apply translational thrust along line of sight (LOS) as required to establish desired closing rate | Manipulate maneuver controller | CA panel |
| | Brake with longitudinal thrusters to bring closing rate near zero when a range 2-3 NM is reached | Manipulate maneuver controller | CA panel |
| | Maintain attitude as required while doing above | Manipulate attitude controller | Center console |
| | Continuously apply translational thrusts while doing above | Manipulate maneuver controller | CA panel |

# GEMINI TASK ANALYSIS

Mission Segment: Rendezvous (Midcourse)

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform guidance and control (cont'd) | Monitor range/range-rate display while doing above | | |
| Perform escape activities as required | Escape activities during Rendezvous (Midcourse) are the same as during Rendezvous (Catch-up) | | |

Mission Segment: Rendezvous (Terminal)

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform timing cycle<br><br>Monitor, report and adjust subsystems as required | Tasks required for these duties are the same as those required for the same duties in Rendezvous (Catch-up) | | |
| Perform guidance and control | Report rendezvous progress | | |
| | Initiate longitudinal braking thrust maneuver at approximately 2 NM LOS range, in order to reduce closing rate to 2-5 fps at about 500 ft. range | Manipulate maneuver controller | CA panel |
| | Control attitude to maintain target boresight | Manipulate attitude controller | Center console |
| | Determine magnitude and direction of corrections to be made to docking radial | | |
| | Apply lateral and vertical thrusts to perform swing-around onto docking radial while maintaining boresight attitude | Manipulate maneuver and attitude controller | CA panel; Center console |

# GEMINI TASK ANALYSIS

Mission Segment: Rendezvous (Terminal)

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform guidance and control (cont'd) | Establish docking attitude reference on attitude sphere | | |
| | Check propellant quantity | | |
| Perform escape activities as required | Tasks during this duty are the same as during the same duty in Rendezvous (Catch-up) | | |

# GEMINI TASK ANALYSIS

Mission Segment: Rendezvous (Docking)

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Program timing cycle<br><br>Monitor, report and adjust subsystems as required | (Tasks required for these duties are the same as those required for the same duties in Rendezvous (Catch-up) | | |
| Perform guidance and control | Apply longitudinal thrust to acquire closing rate of 2 fps prior to radar drop-out (approximately 100 ft.) | Manipulate maneuver controller | CA panel |
| | Set radar to Off | Position detented rotary switch | Pedestal |
| | Set FDR to Platform | Position detented rotary switch | CA panel |
| | Maintain docking attitude | Manipulate attitude controller | Center console |
| | Control spacecraft translation | Manipulate maneuver controller | CA panel |
| | Reduce closing rate incrementally for soft physical contact | Manipulate maneuver controller | CA panel |
| | Report physical contact with target | | |
| Perform emergency activities as required | Actuate maneuver thrusters to clear target vehicle in case of Mission Abort | Manipulate maneuver controller | CA panel |

Mission Segment: Rendezvous (Docking)

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform emergency activities as required (cont'd) | Perform normal Retrograde and Re-entry<br>Follow Emergency Abort procedure of Insertion Segment | | |

# GEMINI TASK ANALYSIS

Mission Segment: Orbit

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| | When not controlling Agena: | | |
| | Set platform to Off | Position detended rotary switch | Pedestal |
| | Set computer to Off | Set toggle switch | Pedestal |
| | Set rate gyros Off | Set toggle switch | Pedestal |
| Prepare for Re-entry | Set event timer to $T_R$-X | Position detented rotary switch | CA panel |
| | Start timer from ground communicated countdown to X | Set toggle switch | CA panel |
| | Monitor spacecraft attitude and rates | | |
| | Maintain system ready for separation | | |
| | Approximately one hour prior to retrofire: | | |
| | Set platform to Cage | Position detented rotary switch | Pedestal |
| | Set scanner to Primary | Set toggle switch | Pedestal |
| | Set yaw rate gyros to Primary | Set toggle switch | Pedestal |
| | Set ACME bias power to Primary | Set toggle switch | OS/CB panel |

Mission Segment: Orbit

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Prepare for Re-entry (cont'd) | Set attitude control to Rate Command | Position detented rotary switch | Pedestal |
| | Set retro Squib batteries to On | Set lever-lock toggle switches | LS/CB panel |
| | Control to SEF attitude | Manipulate attitude controller | Center console |
| | Set platform to Orbit Rate | Position detented rotary switch | Pedestal |
| | Control to BEF attitude | Manipulate attitude controller | Center console |
| | Set platform to BEF | Position detented rotary switch | Pedestal |
| | Set attitude control to Horizon Scan | Position detented rotary switch | Pedestal |
| | Set computer power to On | Set toggle switch | Pedestal |
| | Set computer to Re-entry | Position detented rotary switch | Pedestal |
| | Set rate gyros to Primary | Set toggle switches | Pedestal |
| | Set attitude control to Rate Command | Position detented rotary switch | Pedestal |
| | Report target disengage | | |
| | Set UHF antenna to Re-entry | Set toggle switch | Center panel |
| | Set and verify cabin and suit temperature set to full cold prior to retrograde | Position continuous rotary switch | Center console |

# GEMINI TASK ANALYSIS

Mission Segment: Orbit

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Prepare for Re-entry (cont'd) | Coordinate time of retrofire ($T_R$) and time of chute deploy ($T_C$) over last ground station prior to retrofire | | |
| | Verify that jettison retro squib is on Safe until after retrofire | | |
| Perform emergency activities as required | (Tasks during this duty are the same as those during the same duty in Rendezvous (Docking)) | | |

Mission Segment: Retrograde

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Monitor and maintain retrograde sequence | Control to and maintain retro attitude | Manipulate attitude controller | Center console |
| | Monitor retro attitude | | |
| | Monitor $0_2$ high rate | | |
| | Monitor RCS switch-light | | |
| | Monitor battery power light | | |
| | Actuate Indicate Retro Attitude and verify green light | Depress push button switch-light | Center panel |
| | Actuate $0_2$ High Rate and verify green light | Depress push button switch-light | Center panel |
| | Depress Battery Power switch-light when it turns amber | Depress push button switch-light | Center panel |
| | Verify green illumination of battery power light | | |
| | Set platform to Orbit Rate | Position detented rotary switch | Pedestal |
| | Set OAMS prop to On | Set lever-lock toggle switcn | Pedestal |
| | Set OAMS power to Off | Set lever-lock toggle switch | Pedestal |
| | Set RCS (Ring A & B) to ACME | Set toggle switches | Pedestal |
| | Activate RCS and verify green illumination | Depress push button switch-light | Center panel |

# GEMINI TASK ANALYSIS

Mission Segment: Retrograde

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Monitor and maintain retrograde sequence (cont'd) | Monitor for $T_R$-30 secs. Separate OAMS Lines amber light | | |
| | Monitor for $T_R$-30 secs. Separate Electrical amber light | | |
| | Monitor for $T_R$-30 secs. Separate Adapter amber light | | |
| | Monitor for $T_R$-30 secs. Arm Auto Retro amber light | | |
| | Activate and verify by green illumination Separate OAMS Lines | Depress push button switch-light | Center panel |
| | Activate and verify by green illumination Separate Electrical | Depress push button switch-light | Center panel |
| | Activate and verify by green illumination Separate Adapter | Depress push button switch-light | Center panel |
| | Activate and verify by green illumination Arm Auto Retro | Depress push button switch-light | Center panel |
| | Monitor retrorocket firing at $T_R = 0$ | | |
| | Fire retros manually in case of failure | Depress push button switch | Center panel |

Mission Segment: Retrograde

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Monitor and maintain retrograde sequence (cont'd) | Confirm retrofire | | |
| | Control attitude during and after retrofire | Manipulate attitude controller | Center console |
| | Set RCS (Ring A & B) to Direct in the event of Rate Command System failure and | Set toggle switches | Pedestal |
| | Control RCS manually | Manipulate attitude controller | Center console |
| | Set jettison retro squib to Arm | Set lever-lock toggle switch | LS/CB panel |
| | Monitor for Jettison Retro light (amber) at $T_R$ +45 sec. | | |
| | Actuate Jettison Retro switch-light and verify green illumination | Depress push button switch-light | Center panel |
| | Confirm retro adapter jettison | | |
| | Set retro squib bus to Safe | Set lever-lock toggle switch | LS/CB panel |
| | Establish voice communications when in range of ground stations and report systems and personal status | | |

# GEMINI TASK ANALYSIS

Mission Segment: Retrograde

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform emergency activities as required | Set ejection handle to Ready after retrofire | | |
| | Remove safety from ejection handle | | |
| | Continue normal re-entry in the event of Abort | | |

# GEMINI TASK ANALYSIS

Mission Segment: Re-entry

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Monitor re-entry events | Monitor acceleration buildup | | |
| | Monitor altitude | | |
| | Monitor rate of descent | | |
| Perform re-entry control and guidance | Control to re-entry attitude | Manipulate attitude controller | Center console |
| | Set attitude control to Re-entry | Position detented rotary switch | Pedestal |
| | Set FDR to Computer | Position detented rotary switch | CA panel |
| | Set FDM to Attitude | Position detented rotary switch | CA panel |
| | (The last three steps will automatically establish a $15^{o}$/sec. roll) | | |
| | Set attitude to Rate Command and | Position detented rotary switch | Pedestal |
| | Control roll if automatic roll attitude fails | Manipulate attitude controller | Center console |
| | Set RCS (Ring A & B) to Direct in event of Rate Command System failure and | Set toggle switches | Pedestal |
| | Control re-entry manually | Manipulate attitude controller | Center console |

# GEMINI TASK ANALYSIS

Mission Segment: Re-entry

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform re-entry control and guidance (cont'd) | Actuate Start Computer switch if at $T_C$=0 computer operating light has not illuminated | Depress push button switch | Pedestal |
| | Report applicable systems and personal status | | |
| | Deploy drogue chute at approximately 50,000 ft. | Depress push button switch | Pedestal |
| | Report drogue chute deploy | | |
| | Confirm abort mode changes with second Astronaut | | |
| Perform escape activities as required | Perform normal re-entry in the event of Mission Abort | | |
| | Eject at safe altitude in the event of drogue chute failure | | |

# GEMINI TASK ANALYSIS

Mission Segment: Landing

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform landing sequence | Monitor altitude | | |
| | Monitor rate of descent | | |
| | Initiate main chute deploy at 10,000 ft. | Depress push button switch | Pedestal |
| | Set attitude control to Paraglider | Position detented rotary switch | Pedestal |
| | Monitor paraglider inflation bottle pressure | | |
| | Monitor paraglider wing pressure | | |
| | Depress Fuel Jettison button | Depress push button switch | |
| | Set RCS (Ring A & B) to Off | Set toggle switch | Pedestal |
| | Control to touchdown | Manipulate attitude controller | Center console |
| | (After touchdown) | | |
| | Set landing squib to Safe | Set lever-lock toggle switch | LS/CB panel |
| | Stow D ring (ejection handle) | | |
| | Set ACME bias power to Off | Set toggle switch | OS/CB panel |
| | Set Cryogenic heaters to Off | Depress push button switches | Center panel |
| | Set platform to Off | Position detented rotary switch | Pedestal |
| | Set rate gyros to Off | Set toggle switches | Pedestal |

Mission Segment: Landing

| Duty | Task | Response Element | Instrument/Control Location |
|---|---|---|---|
| Perform landing sequence (cont'd) | Set computer to Off | Set toggle switches | Pedestal |
| | Set attitude indicators to Off | Set toggle switches | LS/CB panel |
| | Stop event timer | Set toggle switches | CA panel |
| | Select #2 audio to HFDF | Position detented rotary switch | Center panel |

# APPENDIX C

# OPERATING INSTRUCTIONS FOR TEST CONSOLE

## LOCATION AND FUNCTION OF CONSOLE COMPONENTS

Figure 5 shows the console control surfaces. The console layout may be conveniently discussed in terms of its three panels: upper, center, and lower.

### Upper Panel

This section contains the two meters, the Arm-Hand Steadiness unit (between meters), and six test-setup selector switches.

#### Meters

The two meters are used to indicate performance error data for the various tracking tasks. They are also the stimulus displays for Time Sharing and Perceptual Speed. Each meter has a three-position switch: $\frac{\cdot}{\cdot}$ 10, OFF, and x1. In the $\frac{\cdot}{\cdot}$ 10 mode, the meter indication is divided by 10. For example, an indication of 45 is read as 4.5. In the x1 position, the meter values are read directly as indicated from 0 to 50.

When performing tracking tasks, the left-hand meter displays error for the vertical (y) axis; the right-hand meter shows error for the horizontal (x) axis. The right-hand meter is used in scoring the tests of Movement Prediction and Movement Analysis.

#### Arm-Hand Steadiness Unit

This unit contains the aperture used in measuring arm-hand steadiness. During this test the upper half of the unit is illuminated in amber and directs the subject to insert the stylus. The lower half is illuminated in green during the 10-second scoring periods. The amber signal is also the warning light for the Wrist-Finger Speed test.

#### Task Selector Switches A, B, and C

From left to right on the upper panel, the first three rotary selector switches are designated as TASK SEL A, B, and C, respectively. Positions on these switches determine the combination of amplifiers, relays, and subject-response switches for each task. Following are the positions and related test functions for each switch.

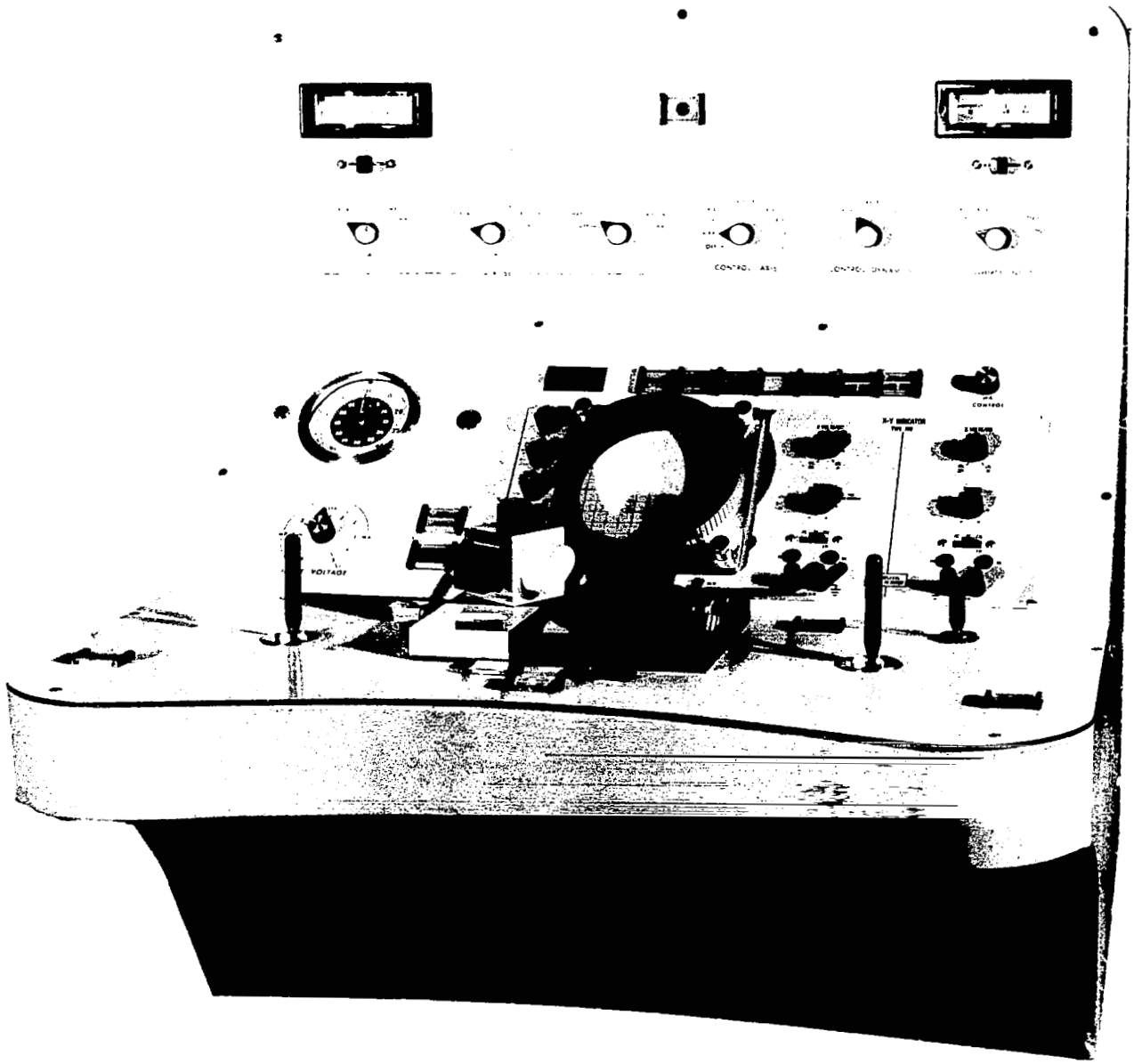


Figure 5. Perceptual-Motor Performance Measurement Console.

TASK SEL A

| Position | Test |
|---|---|
| OFF | ---- |
| CP, R, A (all tracking tasks) | Control Precision, Rate Control, Acceleration Control |
| TS | Time Sharing |
| MP | Movement Prediction |
| MA | Movement Analysis |

TASK SEL B

| Position | Test |
|---|---|
| OFF | ---- |
| CP, R, A (all tracking tasks) | Control Precision, Rate Control, Acceleration Control |
| TS | Time Sharing |
| RT | Reaction Time |
| AHS, WFS | Arm-Hand Steadiness<br>Wrist-Finger Speed |
| RO | Response Orientation |

TASK SEL C

| Position | Test |
|---|---|
| OFF | ---- |
| MAN CL | Manual Clock (permits manual starting and stopping of clock) |
| PS | Perceptual Speed |
| AHS, WFS | Arm-Hand Steadiness<br>Wrist-Finger Speed |
| SAM | Speed of Arm Movement |

## CONTROL/AXIS Selector

This is the fourth switch from the left. It determines which control stick will function and the axis it will control.

| Position | Function |
|---|---|
| OFF | -------- |
| R-XY | Right-hand Control stick operates in horizontal (x) and vertical (y) axes (left-hand control inoperative). |
| L-XY | Left-hand control stick operates in x and y axes (right-hand control inoperative). |
| R-X, L-Y | Right-hand control stick operates in x; left-hand operates in y. |
| R-Y, L-X | Right hand controls y axis; left hand controls x axis. |
| R-X | Right hand controls x axis only (left control inoperative). |
| R-Y | Right hand controls y axis only (left control inoperative). |
| L-X | Left hand controls x axis only (right control inoperative). |
| L-Y | Left hand controls y axis only (right control inoperative). |

## CONTROL DYNAMICS Selector

This is the fifth switch from the left. It determines the system dynamics for the various tracking tests.

| Position | Function |
|---|---|
| POS | Selects "position" control dynamics (zero-order system). Used on Control Precision test. |

| Position | Function |
|---|---|
| RATE | Selects rate control dynamics (first-order system). Used in Rate Control and Multilimb Coordination tests. |
| ACCEL | Selects acceleration control dynamics (second-order system). Used in Acceleration Control test. |

COURSE INPUT Selector

This is the sixth switch from the left. It determines the "course" followed by target dot in the various tracking tests and the movement of meters for the Time Sharing test.

| Position | Function |
|---|---|
| OFF | -------- |
| CP CIRCLE | Selects circle course for Control Precision test. This position provides a "target" dot which travels in a circle and a "follower" dot which is controlled by subject. |
| X & Y, R, A | Selects course in both x and y axes, with either rate or acceleration dynamics as selected on CONTROL DYNAMICS Selector. |
| TS | Selects movement of meter indicator for Time Sharing test. |
| ∿x | Selects movement of target dot back and forth in horizontal (x) plane. |
| ∿y | Selects movement of target dot up and down in vertical (y) plane. |

## Center Panel

This section contains the clock (timer), clock reset switch, clock shield, counter, Movement Analysis (MA) control, Input Voltage Selector, nine micro-switches with integral display lighting, and the cathode ray tube (CRT) x-y indicator.

### Clock

The shorter hand and inner scale indicate elapsed time from 0 to 60 seconds; the longer hand and outer scale indicate 1/100ths of a second.

### Clock Reset

Immediately to the right of the clock is the round, blue reset button which returns the clock hands to zero.

### Clock Shield

Directly to the left of the clock is the receptacle for the clock shield. The shield is keyed to allow covering or exposing the clock as tests require.

### Counter

The first element in the row of components above the CRT is the counter. Its reset button is on the left side of the counter face. To the right of the counter is the switch labeled COUNTER. It is used for manual pulsing of the counter as conditions require.

### RESET

This is the second switch in the row of seven above the CRT. It is used to reset (discharge accumulated voltage) all amplifiers used in tracking, Movement Analysis, and Movement Prediction. It does not reset the sine wave generator amplifiers as this is done automatically by a separate circuit.

### MP (Movement Prediction)

The third switch (MP) is the subject's control for the Movement Prediction test. When this key is depressed, it delivers a selected input voltage to an integrator which causes the dot to move across the CRT. Release of this switch breaks the input and causes the dot to hold its position.

Unlettered Display Unit

The fourth element is a translucent display which is illuminated as red, yellow, green, or white in the test of Response Orientation. This unit is not a switch.

MA (Movement Analysis)

The fifth switch (MA) delivers a selected input voltage to the first of two cascaded integrators, causing the CRT dot to accelerate across the display in the Movement Analysis test.

TARG ADV; A, B. (Target Advance-stepping relay position)

The sixth switch delivers power to the coil of a 10-level, 52-position stepping relay. This relay programs stimulus event sequences for Time Sharing, Response Orientation, Perceptual Speed, Position Estimation, and Position Reproduction. The "TARG ADV" light indicates the end of a stimulus sequence; "A" indicates one of two starting positions; "B" indicates the other. Starting positions for specific tasks are given in the instructions. This switch is used to advance the stepping relay manually as required.

PRO ST; C, T (Program Start; Continuous, Timed)

The seventh switch operates a motor-driven, cam-type programmer which provides timing and sequencing in many of the tests. The "PRO ST" light indicates that the programmer is "off" and ready to be started as needed. If the switch is pressed once and released, the "C" light indicates that the programmer is in its "continuous" mode and will run until the switch is pressed again. By pressing a second time, the programmer is placed into its "timed" mode as indicated by the "T" light. This is the normal operating mode for all tests. In this mode the programmer will operate for the duration of the test set up on the console. At the end of the test, the programmer will stop and the "PRO ST" light will reappear.

To use the timed mode, press once, wait 3 seconds, then press again. Once the programmer has begun operating, it cannot be turned off manually. If a Time Sharing or Response Orientation test trial must be aborted, turn all selector switches to "OFF." Programmer will stop within 60 seconds when in the timed mode.

MA CONTROL (Movement Analysis Control)

This control is at the upper right of the center panel. It is used to

adjust the acceleration component of target dot motion in the Movement Analysis test.

INPUT VOLTAGE Selector; MP, MA (Movement Prediction, Movement Analysis)

This rotary selector is directly beneath the clock. It has two scales (MP on left, MA on right), numbered 1 through 5. The "MP" positions select target dot velocities in the Movement Prediction test. The "MA" positions select target dot acceleration levels for the Movement Analysis test.

POWER

Below and to the right of the clock is the main power switch. It controls all AC and DC power to the console. Press to turn power on. Press again to turn power off.

VIS-AUD (Visual-Auditory Reaction Time)

Directly above the POWER switch is the Reaction Time mode selector. When RT is selected on Task Selector B, the upper or lower half of this switch will be illuminated. "VIS" indicates that the reaction time stimulus is a light (located within RT switch, lower console); "AUD" indicates that the reaction time stimulus is a tone. Simply press to change stimulus conditions.

Cathode Ray Tube (CRT) X-Y Indicator

Before operating this device for the first time:

1. Set all selector switches to "OFF."

2. Turn on POWER on center console.

3. Press RESET above CRT, center panel.

To the left of the CRT face are three control knobs. The bottom knob controls CRT power and scale illumination. Turn this fully clockwise. Red pilot lamp (lower left corner of CRT) and scale markings should appear. Allow one minute for warmup.

Turn intensity control at top left fully clockwise. If dot is visible, adjust intensity to comfortable level. If dot is not visible, continue with following procedure. On the right side of the CRT are the X and Y vernier or gain controls. Turn both fully counterclockwise to detented "1v" position.

Below each vernier knob is a position control. Set both to "12 o'clock" position.

Below each position control is a slide button. Set both to "DC." Dot should now be centered on CRT face.

Adjust focus (left of CRT face, second knob from top).

Turn vernier controls fully clockwise to detented "1v" position. Hold RESET down and recenter dot using X and Y position controls.

The CRT is now ready for use. Further adjustments are specified in the instructions for each test.

Along the bottom right of the CRT case are four terminals; the X and Y inputs have been disconnected. The two ground terminals are used according to instructions. Note: the blue terminal is connected through the counter to ground. The other is a direct connection to ground.

## Lower Panel

The lower panel includes two tracking control sticks, a four-position telever switch, a connector block, and seven microswitches with internal display lighting.

### Connector Block

Directly beneath the CRT face is the spring-loaded aluminum connector block. Its function is to hold in place test components for Manual Dexterity, Finger Dexterity, and Mirror Tracing. When the Mirror Tracing template is inserted, it receives 28v DC through the connector to permit scoring of contacts made with the tracing stylus.

### CLOCK (Manual Control Switch)

At the left rear of the lower panel is the switch used for manual operation of the clock. This switch is illuminated and functional when Task Selector C is set to "MAN CL" or "PS."

Press once firmly to start clock; press again to stop.

### RT (Reaction Time Response Key)

At the right rear of the lower panel is the subject's response key for the

Visual and Auditory Reaction Time test. When testing visual reaction time, this switch is illuminated and constitutes the visual stimulus light. Subject presses and holds until light is extinguished. When testing auditory reaction time, subject presses and holds until tone ceases.

Telever Switch (Subject Response Key for Response Orientation)

This switch is moved either forward, back, left, or right depending upon the colors presented during the Response Orientation test. A correct response extinguishes the stimulus light and stops the timer.

Control Sticks

Each stick operates two linear potentiometers which provide control inputs for the various tracking tasks. The sticks are not spring-centered; they will remain deflected when released. Either stick may control both the horizontal (x) and vertical (y) axes of the CRT display marker. Forward stick movement raises the dot; backward movement lowers the dot. Left and right stick deflections produce corresponding dot movements.

The CONTROL AXIS Selector permits either stick to operate either axis singly or in combination. Thus, the left hand may control y, while the right hand controls x and vice versa. The latter configuration is used in the test of Multilimb Coordination.

SAM; 1, 2, 3 (Speed of Arm Movement; Position Estimation, and Position Reproduction Score)

This switch is at the left front of the lower panel. It serves a dual function. When "SAM" is set on Task Selector C, the "SAM" light indicates that this switch is functional for the Speed of Arm Movement test. Its companion switch, also labeled "SAM," is on the opposite side of the lower panel. When the "SAM" sections are illuminated, the left-hand switch starts the timer; the right-hand switch stops the timer.

The numerals 1, 2, and 3 on the left switch indicate the score made when a target is contacted during Position Estimation or Position Reproduction.

Arrows; R (Target Designation; Score Reset)

This unit is directly in front of the operator on the lower panel. The arrows designate which of three targets (← left, ↑ center, or → right) he is to use on each trial of Position Estimation and Position Reproduction. When a target is contacted, the "R" light appears; the score appears as 1, 2, or 3 on the display at the left front of the lower panel (see SAM; 1, 2, 3).

The "R" indicates that the scoring circuit is to be reset before proceeding. Pressing "R" resets the scoring circuit.

WFS; TS; S--WFS; TS; D

These two switches, located directly in front of the operator on the lower panel are used for three separate tests:

Wrist-Finger Speed (WFS). - When "WFS" is set on Task Selectors B and C, these switches are used in tapping to measure wrist-finger speed. Contacts are registered on the counter.

Time Sharing (TS).- When Time Sharing has been selected on the console, these switches become the subject's response keys. The left-hand switch corresponds to the left-hand meter; the right switch to the right meter. The subject presses the appropriate switch when he detects meter movement.

Perceptual Speed. - In this test, the subject judges whether pairs of meter indications are the same, "S," or different, "D." He presses the switch according to his judgment. A correct response advances the program. An incorrect response registers an error on the counter.

Additional Test Components and Accessories

The following items are stored on the inside surface of the cabinet doors or within the cabinet. Doors are "press-to-open" type.

1. Manual dexterity board (right door)
2. Finger dexterity template and bolts (left door)
3. Mirror tracing maze (left door)
4. Stylus/expansion cord
5. Manual dexterity key
6. Mirror tracing goggles
7. Targets (3)
8. Clock shield
9. CRT hood

10. Switch legend template

11. Manual of operating instructions

## Instructions

Before beginning any tests, it is necessary that the preceding section on console operation be understood. Since many of the same controls are used in different tasks, the following instructions assume that a basic orientation regarding these elements has been achieved. In particular, the function and use of the Target Advance and Program Start switches, the CRT X-Y indicator, and general location of switches should be familiar enough to preclude time-consuming errors in setup and test performance. The location of each element is presented in the foregoing discussion and is designated in less detail within specific test instructions.

Mean scores and the approximate administration time for each test, based on preliminary testing, are presented in Table 4.

### Pretest Procedures

1. Set all selector switches to "OFF," including meters.

2. Switch on POWER.

3. Reset Counter and Clock.

4. Turn MA CONTROL knob fully counterclockwise (↶).

5. Insert clock shield--clock exposed.

6. Insert targets--receptacles on back of panels--targets face front.

7. Remove stylus from storage cabinet.

### Fine Manipulative Abilities

Arm-Hand Steadiness (AHS). - This test measures the steadiness of your arm and hand while held fully extended.

1. Plug the stylus into the blue ground terminal on the CRT case.

2. Set Task Selectors B and C to "AHS, WFS"--all other selectors to "OFF."

TABLE 4

SUMMARY OF PRELIMINARY TEST RESULTS

| Test | Mean Score | Approximate Admin. Time |
|---|---|---|
| **Fine Manipulative Abil's** | | |
| Arm-Hand Steadiness | 56 contacts | 2 min. |
| Wrist-Finger Speed | 149 contacts | 2 min. |
| Finger Dexterity | 88 seconds | 4 min. |
| Manual Dexterity | 53 seconds | 3 min. |
| **Gross Positioning and Movement Abilities** | | |
| Position Estimation | 15 points | 3 min. |
| Response Orientation | 15 seconds | 4 min. |
| Control Precision | 18 (y axis)<br>17 (x axis) | 4-8 min. |
| Speed of Arm Movement | .29 seconds | 2 min. |
| Multilimb Coordination | 33 (y axis)<br>28 (x axis) | 5-10 min. |
| Position Reproduction | 16 points | 3 min. |
| **System Equalization Abilities** | | |
| Movement Analysis #1<br>#2<br>#3<br>#4<br>#5 | 1.0 (absolute<br>0.6 scale adjust-<br>0.4 ment error)<br>0.5<br>0.6 | 10 min. |

(continued)

TABLE 4--Continued

SUMMARY OF PRELIMINARY TEST RESULTS

| Test | Mean Score | Approximate Admin. Time |
|---|---|---|
| System Equalization Abilities--Continued | | |
| Movement Prediction at Angular Velocity | | |
| #1 .0195 (rad/sec)<br>#2 .0369<br>#3 .0553<br>#4 .0830<br>#5 .3688 | .0226 (mean absolute<br>.0144 error/radians)<br>.0175<br>.0226<br>.0257 | 4 min. |
| Rate Control | 16 (y axis)<br>17 (x axis) | 5-10 min. |
| Acceleration Control | 25 (y axis)<br>35 (x axis) | 5-10 min. |
| Perceptual-Cognitive Abilities | | |
| Perceptual Speed | 61 seconds<br>2.4 errors | 3 min. |
| Time Sharing | 30 seconds | 7 min. |
| Reaction Time Ability | | |
| Visual<br>Auditory | .23 seconds<br>.22 seconds | 4 min. |
| Mirror Tracing Ability | | |
| Mirror Tracing | 76 seconds | 3-6 min. |

3. Grasp the stylus as you would hold a pencil. The tip of your index finger should be even with the end of the plastic handle.

4. Extend your arm without locking your elbow and insert the tip of the stylus into the arm-hand steadiness aperture (between the meters). This is the position used during testing.

5. Remove the stylus. During a trial, the lower half of the unit will show an amber light. This is a warning signal which directs you to insert the stylus. In about three seconds, the upper half will show a green light indicating that you are being scored. The green light will remain on for 10 seconds. When it goes off, remove the stylus and rest (about 8 seconds). The amber light will reappear and the procedure will be performed a total of three times. Your score is the total contacts accumulated over the three 10-second test periods.

6. Reset counter if it is not showing all zeros.

7. Start the programmer. Press PRO ST once; wait three seconds, and press again --"T" light on.

8. Perform the three trials as directed by the amber and green lights. Programmer stops after third trial.

9. Record score from counter.

10. Reset counter.

Wrist-Finger Speed (WFS). - This is a test of your ability to make rapid, repetitive, wrist-finger movements. The amber warning light between the meters used in Arm-Hand Steadiness is also the warning light for this test.

1. Reset counter.

2. Set Task Selectors B and C to "AHS, WFS"--all other selectors to "OFF."

3. Directly in front of you on the lower panel are two switches marked WFS. When the top-panel amber warning light comes on, look down at these two switches. In 2-3 seconds the WFS section will be illuminated. This is your signal to begin tapping back and forth between them as rapidly as possible. Use the index finger of your preferred hand. Continue tapping until the WFS lights go out. There are three 10-second trials. Your score is the total contacts accumulated on the counter during these three trials.

4. Start the programmer. Press PRO ST once, wait 3 seconds, press again--"T" light on.

5. Perform the three trials. PRO ST light comes on at end of the last trial.

6. Record score from counter; reset counter.

Finger Dexterity. - This test measures your ability to manipulate small objects with the fingers of both hands.

1. Remove the Finger Dexterity template from the left cabinet door. (Doors are "press-to-open.")

2. Remove the threaded assembly units from their holder on left cabinet door (two parts: one, square; one, hexagonal).

3. Insert the template lip into the connector block below the CRT face.

4. Separate the threaded units. Notice that they may be joined in only one way. The square unit has larger threads. These correspond to the holes on the plate marked with a square. The hexagonal unit has slightly smaller threads. They correspond to the holes marked with a hexagon on the plate. The test is performed in the following sequence:

5. Set TASK SEL C to "MAN CL."

6. Separate the units, holding one in each hand; start timer.

7. Assemble the units (screw them together).

8. Screw assembly to center column hole (hex) nearest you.

9. Retrieve and disassemble.

10. With your left hand, screw the square unit to the first hole (square, nearest to you) on the left; with your right hand, screw the hexagonal unit to the first hole (hex, nearest to you) on the right. You need not use both hands simultaneously.

11. Retrieve and assemble.

12. Screw assembly to square in center column.

13. Retrieve and disassemble.

14. Screw hex unit to hex on left, using left hand; screw square to square on right, using right hand.

15. Retrieve and assemble.

16. Screw assembly to top hole, center column (hex farthest from you); stop timer.

17. Record time; reset clock.

Manual Dexterity. - Remove the Manual Dexterity test board from the right cabinet door. (Doors are "press-to-open.") Insert the lip of the board into the connector block. Remove the Manual Dexterity block from the cabinet.

Notice that the board receptacles and corresponding block surfaces are the same in color. The task is to insert each block projection into its receptacle, moving clockwise twice around the board. The test is performed using one hand. In each instance, the block is retrieved by grasping the projection corresponding to the next receptacle in the sequence. The block is then rotated so as to grasp the opposite projection and then inserted. During retrieval or insertion fingers may not be touching projections other than the one specified in each step. The block is never held by its gray center portion during retrieval or insertion. Any part of the block may be handled during manipulation.

1. Insert the block into the square hole. This is the starting and finishing position.

2. Retrieve the block by grasping the blue circular portion only.

3. Rotate the block in your hand so as to grasp the red square.

4. Insert into the blue circle.

5. Retrieve by grasping yellow diamond.

6. Rotate to grasp green triangle.

7. Insert into diamond.

8. Grasp gray oval.

9. Rotate to grasp black hexagon.

10. Insert into gray oval.

11. Grasp green triangle.

12. Rotate to grasp yellow diamond.

13. Insert into triangle.

14. Grasp black hexagon.

15. Rotate to grasp gray oval.

16. Insert into hexagon.

17. Grasp red square.

18. Rotate to grasp blue circle.

19. Insert into square.

20. Repeat steps 2-19.

21. Stop clock--record score--reset clock.

Gross Positioning and Movement Abilities

Position Estimation (PE). - This tests your ability to reach out and touch a designated location (target) without looking.

1. Remove the three targets from the cabinet and insert firmly into receptacles on back of console.

2. Plug the stylus into the black ground terminal (third from the left) on the lower right side of the CRT case.

3. Set all selector switches to "OFF."

4. Set TARG ADV to "B" (If it is on "A" press 26 times).

5. Press TARG ADV once. One of the three small arrows directly in front of you on the lower panel will be illuminated. These designate the target on each trial: left (←), center ( ↑ ) or right (→).

6. Hold the stylus as you would hold a pencil.

7. Place the tip of the stylus above the arrow and look at the target designated.

8. Return your gaze to the arrow and keep it there.

9. Without looking up, reach up with the stylus and attempt to touch the center of the target.

10. When you contact the target, your score will appear as 1, 2, or 3 on the extreme left of the lower panel. If you miss the target, your score is 0 for that trial.

11. Notice that when a score appears, a small red "R" is illuminated on the ARROW switch. This indicates that the scoring circuit is on and is to be reset by pressing the "R." Record each score before resetting. Score may be kept on the counter by using the COUNTER switch.

12. Press TARG ADV. Another target will be indicated. On occasion the same target may be designated twice in succession.

13. Repeat steps 7-11 for the number of trials prescribed by experimenter. The target advance switch will present a total of 24 targets in random sequence before returning to its "TARG ADV" position followed by starting position "A."

Response Orientation (RO). - This test measures your ability to make a directional control movement (left, right, forward, or back) in response to a nondirectional signal (colored light). The light will appear at the center unit in the row of switches just above the CRT. It is between the MP and MA switches. Your control is the black telever switch on the right-rear of the lower panel.

The following procedure must be carried out in sequence or the apparatus will not function.

1. Set all selectors to "OFF."

2. Set TARG ADV to "A."

3. Set TASK SEL B to "RO." You will hear the stepping relay being cocked. In this position the TARG ADV switch will not operate manually.

4. Learn the following control-display relationships. Practice by moving the telever switch as you recite the signal colors in random order for one minute.

Red: left

Yellow: forward (away from you)

Green: right

White: back (toward you)

5. Reset Clock.

6. Start program--press PRO ST once, wait 3 seconds, press again--"T" light on.

7. When stimulus light appears, perform appropriate directional response as rapidly as possible. Hold the switch in position after responding until you hear the stepping relay advance. It will sound with a "clunk." Failure to hold will re-start the timer. Release when you hear the stepper advance.

8. Continue until sequence ends indicated by "PRO ST" light.

9. Record time--reset clock.

Note: To repeat this test, turn TASK SEL B one position counter-clockwise to "AHS, WFS" so as to release stepping relay. Then pulse TARG ADV until "A" appears again. This test will not operate from TARG ADV position "B."

Control Precision (CP). - Your ability to make fine, continuous, and controlled positioning movements is measured here by a two-axis tracking task. The test requires the use of a single control stick which controls a marker dot in two axes of motion on the CRT. A target dot travels in a clockwise circle. Your task is to keep your "follower" dot superimposed upon or as close as possible to the target dot. This may be accomplished best by moving the control in a smooth clockwise circle. Forward stick movement raises your dot, backward movement lowers it. Left and right stick movements produce corresponding movements of your dot.

Observe the CRT setup procedures given earlier before continuing.

1. Set TASK SEL A and B to "CP, R, A"

   TASK SEL C to "OFF"

   CONTROL AXIS SEL to "R-XY"

   CONTROL DYNAMICS to "POS"

   COURSE INPUT to "CP CIRCLE"

Two dots should now be present on the CRT. Your right-hand stick should control one of these dots. Check to see that it does by moving the stick.

2. With your left hand, hold the RESET button down. With your right hand center your follower dot on the CRT by using the X and Y position controls on the CRT; then set X and Y vernier (gain) controls to "12 o'clock" (5v per cm). One dot should be on center, the other should be on the Y axis at the bottom line of the grid (6 o'clock).

3. Set meters to "x1."

4. Start programmer--press PRO ST once, wait 3 seconds, press again--"T" light on.

The course will run for one minute. Score is taken over the final 56 seconds. Score from each previous trial is reset automatically after 4 seconds of next trial.

5. Continue tracking for 1 minute. "PRO ST" indicates end of trial.

6. Read Y score on left-hand meter, X score on right-hand meter. Score is time integral of absolute value of error voltage.

To repeat trial simply restart programmer. Score resets automatically.

Speed of Arm Movement (SAM). - This test measures the speed at which you can move your arm between two designated points. These points are the two switches marked "SAM" on the left and right of the lower panel. Set TASK SEL C to "SAM." The "SAM" sections of the response keys are illuminated indicating that they are now functional for this test.

1. Reset clock.

2. Hold your right hand (palm down, fingers extended) slightly above left "SAM" key.

3. At your own discretion strike the left key (starting clock) and move your arm as rapidly as possible to the right to strike right-hand "SAM" key (stopping clock).

4. Record elapsed time for single movement--reset clock.

Multilimb Coordination. - The ability to make coordinated hand movements is measured here using a two-hand, compensatory tracking task in two axes. Your left hand controls target motion in the Y (vertical) axis; left hand controls motion in the X (horizontal) axis. Your task is to keep the CRT dot centered on the display by simultaneous use of both hands.

Observe CRT setup procedures given earlier before continuing.

1. Set TASK SEL A and B to "CP, R, A"

   TASK SEL C to "OFF"

   CONTROL/AXIS to "R-X, L-Y"

   CONTROL DYNAMICS to "RATE"

   COURSE INPUT TO "X & Y, R, A"

2. Turn CRT X and Y vernier controls fully clockwise to detented 1v per cm position.

3. Depress RESET and hold; center dot using CRT position knobs.

4. Set meters to "x1."

5. Obtain control of dot using control sticks--press RESET to recover "lost" dot.

6. When dot is under control and approximately centered, start programmer. Press PRO ST twice--"T" light on.

7. Continue tracking for one minute--"PRO ST" indicates end of trial.

8. Error is scored over final 56 seconds of tracking. Record Y error from left meter; X error from right meter.

Position Reproduction (PR). - This is a test of your ability to reproduce or repeat a discrete arm-hand movement without the aid of vision. The test is performed as in Position Estimation with the following modification. Here you are required first to actually perform the movement (contact the target designated) while looking, then return your hand and eyes to the starting position and repeat the same movement without looking up.

Note: Upon making your initial movement a score will register--simply touch the stylus to the red "R" to reset before repeating movement.

System Equalization Abilities

Movement Analysis (MA). - A measure of your ability to detect acceleration in the motion of a target dot is obtained in the following manner: The dot will move across the CRT at a preset velocity and acceleration. Your task is to adjust the system so that the dot moves at a constant velocity.

Observe CRT setup procedures before continuing. Press RESET to recover lost dot.

1. Set TASK SEL A to "MA" (farthest clockwise position). All other selectors to "OFF." Meters to "OFF."

2. (a) Turn CRT Y axis vernier knob fully counterclockwise to "10v" position.

(b) Turn X vernier fully clockwise to "1v" position.

(c) Set CRT Y position knob to "12 o'clock."

(d) Adjust X position knob to set dot on furthermost right-hand grid line while holding RESET down.

3. Turn MA control knob (top right of center panel) fully counterclockwise. This is your acceleration adjustment control used during the test. It must be turned to this position before beginning each of the five acceleration conditions.

4. Set INPUT VOLTAGE SEL to "1" on MA (right) scale.

5. Press MA switch above CRT --illuminated in yellow; remains on for remainder of test.

6. Press RESET and observe dot as it moves from right to left across CRT.

7. Turn MA control knob some amount clockwise.

8. Press RESET and observe.

9. Repeat steps 7 and 8 until you feel that the dot is moving at a constant velocity, neither accelerating nor decelerating. The effect of an MA control adjustment will only be reflected after each RESET. Adjustments made while the dot is traversing the display will result in acceleration. Ignore this. Press RESET and observe true effect.

10. Set left-hand meter to "x1" and record indication.

11. Advance INPUT VOLTAGE SEL to "2," "3," "4," and "5," repeating steps 6-10 at each setting.

12. At end of session, set INPUT VOLTAGE SEL to "OFF"; turn MA control fully counterclockwise, press MA (yellow light off). If MA switch is left on, other tasks will malfunction.

Movement Prediction (MP). - The ability to predict the position of a moving target after it has been obscured from view is measured by this test. A dot will move across the CRT at each of five preset constant velocities. Midway across the CRT, it will disappear. Your task is to judge when the dot has arrived at the right-hand edge of the display grid.

Observe CRT setup procedure before continuing.

1. Set TASK SEL A to "MP." All other selectors to "OFF."

2. (a) Turn CRT Y vernier fully counterclockwise to "10v" position.

(b) Turn CRT X vernier fully clockwise to "1v" position.

(c) Use CRT Y position control knob to set dot slightly above X axis.

(d) Depress RESET and hold; turn X position knob so that the dot is just out of sight on left side of CRT.

(e) Set INPUT VOLTAGE SEL to "1" on MP (left) scale.

(f) Set right-hand meter to "x1."

(g) Press and hold MP button above CRT. Dot moves from left to right; pulse MP button until meter reads "36."

(h) With meter at "36," use X position knob to set dot directly on furthermost right-hand grid line.

(i) Press RESET; repeat steps g and h to verify calibration; "36" is reference around which performance scores are taken.

3. With VOLTAGE INPUT SEL on "1," press RESET; then press and hold MP. Dot moves across and disappears. Continue to hold MP. Release when you think dot has arrived at right-hand edge of grid.

4. When MP is released, dot reappears and holds--dot position is shown on meter. Record score.

5. Advance INPUT VOLTAGE SEL to "2-5," repeating steps 3 and 4 at each velocity setting. Table 5 gives conversion factors for obtaining error in radians. Values are based on 30 cm viewing distance provided by CRT hood.

TABLE 5

MOVEMENT PREDICTION SCORE-CONVERSION SCALE

UNITS TO RADIANS

| Movement Prediction Score (± Scale units re: reference value) | Radians* |
|---|---|
| 0.5 | .0166 |
| 1.0 | .0332 |
| 2.0 | .0664 |
| 3.0 | .0996 |
| 4.0 | .1328 |
| 5.0 | .1660 |

*Based on 30 cm viewing distance and 3.1 scale units per cm on CRT.

Rate Control. - This is the ability to operate a first-order (rate) control system in a two-axis compensatory tracking task. A single control stick is used to maintain a target dot centered on the display. Forward stick movement raises the dot; backward stick movement lowers the dot; left and right stick movements produce corresponding dot movements.

1. Set TASK SEL A and B to "CP, R, A."

   TASK SEL C to "OFF"

   CONTROL/AXIS to "R-XY"

   CONTROL DYNAMICS to "RATE"

   COURSE INPUT to "X & Y, R, A"

2. Depress RESET and hold; turn X and Y CRT vernier knobs fully clockwise to "1v." Use CRT position knobs to center dot. Centering must be accurate or scoring will not be valid.

3. Set meters to "x1."

4. Obtain control of dot with control stick.

5. Start programmer; press PRO ST twice--"T" light on.

6. Continue tracking for one minute; end of trial indicated by PRO ST.

7. Record Y error from left meter; X error from right meter.

Acceleration Control. - This test is performed as in Rate Control above, with the following modification: set CONTROL DYNAMICS to "ACCEL." All other settings and procedures are identical to Rate Control.

NOTE: If the operator cannot control this system at first, he should reduce the CRT display gain (verniers) to 12 o'clock position, recenter the dot while depressing RESET and practice until sufficient skill is developed. Whenever vernier adjustments are made, the dot must be recentered.

Perceptual-Cognitive Abilities

Perceptual Speed (PS). - This is the ability to make rapid visual comparisons of display elements. A series of values are presented in pairs on the

console meters. Your task is to decide as quickly as possible whether the values on each meter are the same or different.

1. Set TASK SEL C to "PS," all other selectors to "OFF." MA switch above CRT must be "OFF" (no light).

2. Set TARG ADV to "B."

3. Set meters to "x1." If voltage registers, press RESET to clear meters.

4. Notice that the CLOCK switch is illuminated and functional for use in timing this test; also, directly in front of you on the lower panel, two switches, "S" and "D," are illuminated. These are your response keys. Press "D" if meters are different; press "S" if meters are same. An incorrect response will register an error on the counter; a correct response advances the meter sequence.

5. Reset clock and counter.

6. You are now ready to begin. The meters should both be reading zero. At the same time, press the CLOCK button firmly and the "S" key. This will start the clock and present the first pair of values in the sequence.

7. Continue responding as "S" or "D" until end of sequence is indicated by TARG ADV light. Stop clock immediately.

8. Record time and errors. Reset clock and counter.

Time Sharing (TS). - The ability to divide your attention continuously between display elements is measured by this test. Your task is to monitor the two console meters in order to detect indicator movement.

1. Set TASK SEL A, B, C, and COURSE INPUT to "TS," all other selectors "OFF."

2. Set TARG ADV to either "A" or "B," then pulse one time.

3. Set meters to "x1." Press RESET.

4. Notice that the "TS" sections of the switches in front of you on the lower panel are illuminated. These are your response keys for reporting detection of meter movement. The left key corresponds to the left meter; right key to right meter. Sometime after starting the programmer, you will

detect meter movement. Press the corresponding key and hold until the movement stops. Failure to do so will restart the timer and your score will not be valid. Always press the correct switch. Any errors will abort the test and it must then be started over again. The test period is four minutes.

5. Reset clock; cover with shield.

6. Start programmer. Press PRO ST twice--"T" light on.

7. Monitor both meters. Respond rapidly and hold until meter stops. "PRO ST" indicates end of test.

8. Record accumulated response time; reset clock.

Reaction Time Ability

Reaction Time (RT). - This test determines how rapidly you can respond to a light or tone by pressing a switch.

1. Set TASK SEL B to "RT." All other selectors are "OFF."

2. Notice that a section of the VIS-AUD switch to the left of the CRT is illuminated. "VIS" indicates that the stimulus will be a light. The light is within the RT response key at the right-rear of the lower panel. (This switch lights up as your signal. "AUD" indicates that the stimulus will be a tone emitted from within the console.

3. Press VIS-AUD to select mode. Reset clock; start programmer. Press PRO ST twice--"T" light on.

4. Hold first two fingers of right hand slightly above RT response key.

5. When signal occurs, press and hold until signal stops (light goes out or tone stops). Failure to hold will restart timer and invalidate score.

6. There will be four stimulus presentations approximately ten seconds apart. Record reaction time and reset clock after each signal.

Mirror Tracing Ability

Mirror Tracing. - This test measures your ability to make directional arm-hand movements when visual information is inverted by a mirror.

1. Remove the maze from the left-hand cabinet door and insert lip into connector block on lower panel.

2. Plug stylus into blue ground terminal on lower right of CRT case. Be certain to use the blue terminal only.

3. Set TASK SEL C to "MAN CL" (manual clock).

4. Reset clock.

5. Put on and adjust mirror goggles so that you have a comfortable view of the entire maze.

6. Grasp stylus as you would hold a pencil. Do not touch metal portion of stylus.

7. Place tip of stylus at lower right-hand corner of maze. Move the stylus slightly to orient yourself. You will move clockwise around the maze.

8. Resume starting position; reset counter.

9. At your discretion, press CLOCK firmly with left hand and begin tracing.

10. Stop clock when you return to starting position.

11. Record time and contacts (from counter). Reset clock and counter.

NOTE: The maze is constructed to permit use in any of four orientations.

## ABSTRACT

The purpose of this project was to develop a prototype battery of tests suitable for measuring the primary dimensions of perceptual-motor performance. An extensive survey was made of the technical literature concerning perceptual-motor performance, with particular attention given to factor analytic investigations. Based on results of this survey and a consideration of the kinds of activities likely to be required of crewmen in space vehicles, eighteen basic perceptual-motor abilities were identified as important. An integrated console was developed which would provide separate measures for each of these performance dimensions. Tests such as these will be of value in assessing the influence of the space environment on human performance.

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