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Utility of Five Psychomotor Abilities for First-Term Navy Enlisted Performance

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The psychomotor ability literature was reviewed to evaluate the validity, incremental validity (over general ability), and computer adaptability of tests measuring five psychomotor abilities (multilimb coordination, control precision, arm-hand steadiness, finger dexterity, manual dexterity). The validity results indicated that tests of multilimb coordination, control precision, finger dexterity, manual dexterity have shown useful levels of validities. Incremental validity results were limited and mixed, with multilimb coordination tests showing most promise. Computer tests with useful levels of validity were found for two psychomotor abilities--multilimb coordination and control precision. No computer tests or computer-adaptable tests were found for manual dexterity and finger dexterity. Overall, the results suggest that computerized measures of multilimb coordination and control precision may be useful for Navy selection and classification.

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FOREWORD

This is the final report in a series of three designed to evaluate the importance and relevance of psychomotor ability to Navy enlisted performance. The first report (NPRDC TN 88-44) reviewed the literature on the reliabilities and validities of psychomotor ability tests for predicting training or job performance. The second (NPRDC TN 89-2) described the results of interviews with Navy training school instructors to determine the relative importance they think psychomotor abilities have in determining job performance in 19 Navy ratings. The present report summarizes the results of the first two reports and draws conclusions and recommendations about whether and in what manner psychomotor tests should be added to the Armed Services Vocational Aptitude Battery (ASVAB) on an experimental basis.

This report was prepared by Personnel Decisions Research Institute under Delivery Order #7J03, Contract #N66001-87-D-0085, issued by the Navy Personnel Research and Development Center. It was funded by the Office of the Assistant Secretary of Defense (Force Manpower and Personnel) to accelerate the development of new measures of ability that could be used to supplement the current ASVAB.

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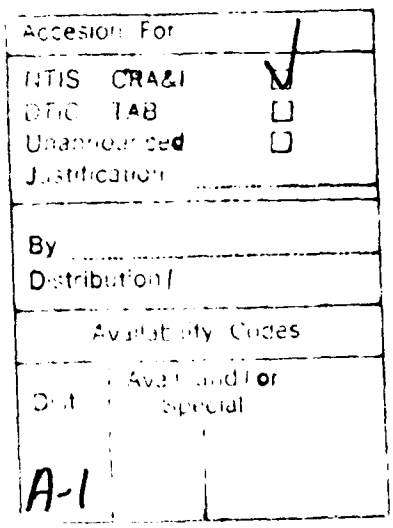

SUMMARY

Problem

The Navy Personnel Research and Development Center is interested in the potential usefulness of computerized psychomotor tests for the prediction of performance in Navy ratings.

Purposes

The purposes of this report are to (1) review the validity evidence for measures of five psychomotor abilities that were found important in a recent survey of Navy ratings (Bosshardt, 1988b); (2) review the incremental validity evidence (over general ability) for measures of these abilities; and (3) identify promising psychomotor tests that have been or could be adapted to computerized administration.

Approach

The psychomotor test literature was reviewed to determine the validity and incremental validity (over general ability) of measures of five psychomotor abilities (multilimb coordination, control precision, arm-hand steadiness, finger dexterity, manual dexterity). Promising tests were identified and then examined for adaptability to computerized administration.

Results and Discussion

Tests of four psychomotor abilities (multilimb coordination, control precision, finger dexterity, manual dexterity) were found to have useful levels of validities. The limited data on the incremental validities of psychomotor tests (over general ability measures) showed mixed results, with multilimb coordination tests showing greatest promise. Computerized psychomotor tests with useful levels of validity were found for two psychomotor abilities--multilimb coordination and control precision. No computer tests or computer-adaptable tests were found for manual dexterity and finger dexterity.

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INTRODUCTION

Problem

The Navy Personnel Research and Development Center (NAVPERSRANDCEN) is interested in exploring the potential usefulness of psychomotor tests for classification of entry-level recruits into Navy ratings. These psychomotor tests would supplement the tests included on the Armed Services Vocational Aptitude Battery (ASVAB), which measure several cognitive abilities important to success in Navy ratings.

Objectives

The objectives of this report are to (1) summarize available validity evidence for measures of five psychomotor abilities (multilimb coordination, control precision, arm hand steadiness, finger dexterity, manual dexterity) that were found important for successful job performance in a survey of 19 Navy ratings (Bosshardt, 1988b); (2) summarize available evidence regarding the incremental validities (over general ability) for measures of these psychomotor abilities; and (3) identify promising measures of these abilities that have been or could be adapted to computerized administration.

Background

The Navy has used the ASVAB for several years to select and classify new recruits into enlisted ratings. The ASVAB measures several cognitive attributes including verbal ability, arithmetic ability, math reasoning and knowledge, mechanical comprehension, perceptual speed and accuracy, general science knowledge, automotive/shop knowledge, and electronics knowledge.

Recently the Navy initiated a research program to determine whether psychomotor abilities would improve prediction of first-term enlisted performance if used in combination with the ASVAB. The initial step in this program was a review of the psychomotor ability/test literature to identify the different types of psychomotor abilities, to identify tests that measure these psychomotor abilities, and to obtain information regarding the validities, reliabilities, and practice effects of these tests, as well as their intercorrelations with abilities measured by the ASVAB. Results of this review (Bosshardt, 1988a) indicated there are nine types of psychomotor abilities (aiming, arm-hand steadiness, control precision, finger dexterity, manual dexterity, multilimb coordination, rate control, speed of arm movement, wrist-finger speed). Measures of five of these abilities (arm-hand steadiness, control precision, finger dexterity, manual dexterity, and multilimb coordination) predicted job and training criteria in military and civilian settings. Other results indicated that psychomotor tests typically have high test-retest and internal consistency reliabilities, low correlations with ASVAB-related abilities and knowledges, and large practice effects.

A follow-up investigation (Bosshardt, 1988b) explored the importance of these psychomotor abilities for first-term performance in 19 Navy ratings. Thirty-eight Navy subject matter experts (SMEs) ("A" school training instructors) completed a questionnaire designed to determine the importance of nine psychomotor and eight ASVAB abilities for first-term rating performance. The results indicated that five psychomotor abilities (multilimb coordination, control precision, arm-hand steadiness, manual dexterity, and finger dexterity) were important for performance in several ratings. Ratings for which psychomotor abilities were judged important included Aviation Antisubmarine Warfare

Operator, Boiler Technician, Aviation Electrician's Mate, Gunner's Mate, Dental Technician, Aviation Machinist Mate, Engineman, Air Traffic Controller, and Hull Maintenance Technician.

EVALUATION OF SELECTED PSYCHOMOTOR TESTS

In this section, measures of arm-hand steadiness, control precision, finger dexterity, manual dexterity, and multilimb coordination are reviewed. These measures are reviewed according to their validity, incremental validity (over general ability measures), and adaptability to computerized administration.

Definitions of these psychomotor abilities are given in Table 1.

Table 1

Definitions of Five Psychomotor Abilities

Arm-Hand Steadiness
This is the ability to make precise arm-hand positioning movements where strength and speed are minimized; the critical feature, as the name implies, is the steadiness with which such movements can be made. The ability extends to tasks in which a steady arm or hand position is to be maintained.
Control Precision
This factor is common to tasks that require fine, highly controlled, but not over-controlled muscular adjustments, primarily where larger muscular groups are involved. This ability extends to arm-hand as well as to leg movements. It is most critical where such adjustments must be rapid, but precise.
Finger Dexterity
This is the ability to make skillful, controlled manipulations of tiny objects involving, primarily, the fingers.
Manual Dexterity
This ability involves skillful, well-directed arm-hand movements in manipulating fairly large objects under speed conditions.
Multilimb Coordination
This is the ability to coordinate the movements of a number of limbs simultaneously, and is best measured by devices involving multiple controls. The factor has been found general to tasks requiring coordination of two feet, two hands, and hands and feet.

Validity of Psychomotor Tests

This section summarizes the validity evidence for various measures of arm-hand steadiness, control precision, finger dexterity, manual dexterity, and multilimb coordination. Since a thorough review and discussion of the validity evidence for various psychomotor tests was recently completed by Bosshardt (1988a)[1] as the initial step in this research program, this section will briefly summarize the major findings of that review.

Table 2 presents a summary of validity results for psychomotor tests that measure the five abilities under consideration.[2] Descriptions of these tests are provided in the Appendix. A brief discussion of the validity evidence for each type of psychomotor ability is presented below.

Arm-Hand Steadiness

Results shown in Table 2 indicate that arm steadiness measures typically have low correlations with training criteria. The median validity coefficient across tests was .05. The highest median validity (.13) is for the Steadiness Aiming Test and is based on a single study. Of the 16 validity studies involving arm-hand steadiness measures, only one study reported a validity coefficient greater than .15 (see Bosshardt, 1988a, Appendix B).

To summarize, only three arm-hand steadiness tests were found that had validity information and all three had low validities. Overall, these results suggest that measures of arm-hand steadiness have limited utility for predicting training performance.

Control Precision

Table 2 presents validity results for four measures of control precision against various training criteria. The results indicate that three tests (Pursuit Confusion Test, Dial Setting Test, Target Tracking Test 1) have median validities of .25 or higher. The median validity for the Target Tracking Test 1 is especially high (.55), but is based on only one study. The median validity across all studies was .17.

In summary, three of four control precision tests reviewed have shown useful levels of validity in previous studies. Of these, the Target Tracking Test 1 appears to be the most promising.

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[1]Literature search activities for that review included: (1) conducting computerized searches using the PSYCINFO data base; (b) reviewing reference sections of relevant articles and reports; (c) contacting researchers who are active in psychomotor testing; and (d) checking the last several years' editions of selected journals (e.g., Perceptual and Motor Skills, Journal of Motor Behavior), as well as textbooks, and handbooks. Overall, nearly 200 reports, articles, papers, and manuals were reviewed.

[2]This table is adapted from Bosshardt (1988a), Table 3.

Table 2

Summary of Validity Results for
Selected Measures of Five Psychomotor Abilities

		Validity Results[a]		
		Criterion		
Construct	Test	Job	Trg	Other
ARM HAND STEADINESS	Arm Hand Steadiness Test	---	.06[b] (13)	---
	Steadiness Aiming Test	---	.13 (1)	---
	Line Control	---	-.10 (2)	---
CONTROL PRECISION	Rotary Pursuit Test	---	.14 (27)	---
	Pursuit Confusion Test	---	.30 (1)	---
	Dial Setting Test	---	.25 (2)	---
	Target Tracking Test 1	---	.55 (1)	---
FINGER DEXTERITY	Santa Ana Finger Dexterity Test	-.05 (2)	.08 (41)	---
	Purdue Pegboard	.30 (14)	---	.70 (1)
	O'Connor Finger Dexterity Test	.04 (16)	.28 (1)	---
	GATB - Finger Dexterity	---	---	.20[c] (562)
	Crawford Small Parts Dexterity Test	.28 (14)	.37 (4)	.29 (1)
	Pinboard Test	.15 (1)	.02 (1)	---
MANUAL DEXTERITY	Minnesota Rate of Manipulation Test	.21 (9)	---	.46 (3)
	GATB - Manual Dexterity	---	---	.20[c] (561)

Table 2 (continued)

Construct	Test	Validity Results[a] Criterion: Job	Trg	Other
MANUAL DEXTERITY (continued)	Stromberg Dexterity Test	---	---	.29 (1)
	Hand Tool Dexterity Test	.29 (9)	.34 (2)	.32 (1)
	Pennsylvania Bi-Manual Work Sample	---	---	.10 (1)
	Formboard Test	.02 (1)	.00 (1)	---
	Peg Turning	---	.07 (2)	---
	Peg Placing	---	-.06 (2)	---
MULTILIMB COORDINATION	Two-Hand Pursuit Test	.43 (3)	.26 (11)	---
	Two-Hand Coordination Test (Melton, 1947)	.15 (10)	.28 (54)	---
	Two-Hand Coordination Test (Sanders et al., 1971)	---	.15 (2)	---
	Rudder Control Test	---	.26 (29)	---
	Complex Coordination Test (Melton, 1947)	.16 (3)	.29 (57)	---
	Complex Coordination Test (Sanders et al., 1971)	---	.19 (4)	---
	Bi-Manual Coordination Test	---	.22 (3)	---
	Target Tracking Test 2	---	.51 (1)	---

[a] Trg = Training Criteria; Other = Educational or other criterion measures

[b] The top entry in each cell of the validity results section is the median correlation between the psychomotor predictor and criterion type. The bottom entry is the number of correlations located for this test-criterion type combination.

[c] Includes validity studies using job, training, and education criteria.

Finger Dexterity

Validity results for six finger dexterity measures are also presented in Table 2. The results indicate that the Purdue Pegboard and Crawford Small Parts Test have median validities of about .30 or greater with various criteria, the GATB-Finger Dexterity Test has a median validity of .20, and the Santa Ana Finger Dexterity Test, O'Connor Finger Dexterity Test, and Pinboard Test have relatively low validities. The median validity across all studies was .19.

Overall, these results suggest that three finger dexterity tests--Purdue Pegboard, GATB-Finger Dexterity, Crawford Small Parts Dexterity Test--may be useful in prediction.

Manual Dexterity

Results presented in Table 2 indicate that four measures of manual dexterity (Rate of Manipulation, GATB-Manual Dexterity, Stromberg Dexterity Test, and Hand Tool Dexterity Test) have median validities of .20 or greater across criteria. Four other manual dexterity tests (Pennsylvania Bi-Manual Work Sample, Formboard Test, Peg Turning, Peg Placing) have median validities of .10 or lower. The median validity across all studies was .20.

In summary, four measures of manual dexterity (Minnesota Rate of Manipulation, GATB-Manual Dexterity, Stromberg Dexterity Test, and the Hand Tool Dexterity Test) have shown useful levels of validity in predicting job and training performance.

Multilimb Coordination

Table 2 also presents validity results for eight measures of multilimb coordination. Results indicate that all eight tests have median validities of .15 or greater across criteria. Seven tests (Target Tracking Test 2, Two-Hand Coordination Test (Melton, 1947), Rudder Control Test, Complex Coordination Test (Melton, 1947), Complex Coordination (Sanders, Valentine, & McGrevey (1971), Two-Hand Pursuit Test, Bi-Manual Coordination Test) have average validities of .19 or greater. One test, Target Tracking Test 2, had a validity of .51 with a training simulation criterion (see Bosshardt, 1988a, Appendix B). The median validity across studies was .27.

Based on these results, seven measures of multilimb coordination (Target Tracking Test 2, Two-Hand Coordination Test (Melton, 1947), Rudder Control Test, Complex Coordination Test (Melton, 1947), Complex Coordination (Sanders et al., 1971), Two-Hand Pursuit Test, Bi-Manual Coordination Test) might be useful for selection. Of these, the Target Tracking Test 2 appears to be the most promising test.

Summary: Validity Evidence

Previous validity results for 29 psychomotor tests measuring five abilities were reviewed. Selected measures of four abilities (multilimb coordination, finger dexterity, manual dexterity, control precision) were found to predict job and training criteria. Measures of arm-hand steadiness were found to have low validities. Table 3 lists the psychomotor tests that have shown useful levels of validity in previous studies.

Table 3

Measures of Four Psychomotor Abilities With Highest Validities in Previous Studies

Control Precision
Target Tracking Test 1
Dial Setting Test
Pursuit Confusion Test
Finger Dexterity
Purdue Pegboard
GATB-Finger Dexterity
Crawford Small Parts Dexterity Test
Manual Dexterity
Minnesota Rate of Manipulation
GATB-Manual Dexterity
Hand Tool Dexterity Test
Stromberg Dexterity Test
Multilimb Coordination
Target Tracking Test 2
Bi-Manual Coordination Test
Rudder Control Test
Two-Hand Coordination Test (Melton, 1947)
Complex Coordination (Melton, 1947)
Complex Coordination (Sanders et al., 1971)
Two-Hand Pursuit Test

Incremental Validity of Psychomotor Tests Over General Ability

Evidence regarding the incremental validity of psychomotor tests over measures of general ability is limited. Although psychomotor tests have been used in combination with general ability tests in many studies, few researchers have reported the incremental validity of psychomotor measures.

Some researchers have examined the incremental validity of combinations of psychomotor tests over general ability measures. For example, Fleishman (1954) examined the incremental validity of a set of four psychomotor tests (Complex Coordination, Rotary Pursuit, Rudder Control, Discrimination Reaction Time) in addition to the Aircrew Classification Battery (ACB). Using graduation-elimination from pilot training as the criterion, addition of these four psychomotor tests to the ACB increased validity from .47 to .57 for a sample of about 1200 pilot cadets.

McGrevy and Valentine (1974) investigated the incremental validity of two computerized measuring multilimb coordination tests (Two Hand Coordination, Complex Coordination) over the Air Force Officer Qualifying Test. Using graduation-elimination from pilot training as the criterion and a sample of 92 Air Force officer trainees, addition of both psychomotor tests increased the validity from .37 to .56.

McHenry, Hough, Toquam, Hanson, and Ashworth (1987) examined the mean incremental validity of a set of computerized perceptual-psychomotor measures over the ASVAB across nine Army enlisted jobs. Five criterion variables (core technical proficiency, general soldering proficiency, effort and leadership, personal discipline, physical fitness and military bearing) were formed from various job knowledge, work sample, and rating measures. Sample sizes ranged from about 300 to 600 per job. Results indicated that the set of psychomotor-perceptual tests added only .01 to .02 to the ASVAB in predicting each of the criterion variables. Results were not reported separately by occupation.

Hunter (1981, 1983) suggested the utility of psychomotor tests depends on the complexity of the job under consideration. In a review of 515 validity studies involving the General Aptitude Test Battery (GATB), Hunter found the incremental validity (over general cognitive ability) of a combination of three psychomotor test scores (finger dexterity, manual dexterity,motor coordination) increased as job complexity decreased. Furthermore, when job complexity was low, the contribution of psychomotor tests was greater than for the cognitive measures. Complexity was defined in terms of Fine's (1955) data, people, and things dimensions.

Table 4 presents a summary of studies that examined the incremental validity of individual psychomotor tests over general ability. The results indicate that psychomotor tests typically add only modest amounts (e.g., .01 to .06) to general ability in predicting various job and training criteria, although one computer psychomotor test (Complex Coordination) had incremental validities greater than .20 in one study (McGrevy & Valentine, 1974).

Incremental validity results according to type of psychomotor ability are limited. Table 4 includes only two studies that examined the incremental validity of multilimb coordination tests, only one study that examined the incremental validities of manual dexterity, finger dexterity, and arm-hand steadiness tests, and no studies that examined control precision measures. The limited information available suggests that measures of multilimb coordination may have some incremental validity.

Finally, it should be mentioned that any conclusions about the incremental validity of psychomotor tests must be made cautiously. The number of studies, predictors, and types of jobs examined is very limited and the sample sizes in the studies reported are generally small.

Summary: Incremental Validity of Psychomotor Tests Over General Ability

To summarize, evidence regarding the incremental validity of psychomotor tests over general ability is both limited and mixed. Fleishman (1954) and McGrevy and Valentine (1974) found combinations of psychomotor tests contributed beyond general ability to the effective selection of pilots. In contrast, McHenry et al. (1987) found a set of computerized psychomotor-perceptual tests added little beyond the ASVAB to the prediction of five criteria across several Army occupations. Hunter (1981, 1983) suggested that job complexity moderates the utility of psychomotor tests, with psychomotor tests showing greatest incremental validity when job complexity is low.

Research on the incremental validity of individual psychomotor tests over general ability typically has found only modest increases in validity, although the number of studies, predictors, and jobs examined was limited and the sample sizes in these studies were small. One computer test of multilimb coordination (Complex Coordination) did add over .20 beyond the Air Force Officer Qualifying Test to the prediction of pilot training success.

Table 4

Summary of Incremental Validity Results for Selected Measures of Four Psychomotor Abilities

Construct	General Ability Test(s)	Psychomotor Test(s)	Sample	Criterion	Validity Results			Reference
					General Ability Test(s) Only	All Tests	Incremental Validity	
ARM HAND STEADINESS	Mechanical Math General Intelligence Table Reading Seven background, personality, and interest scales	Lafayette Hand Steadiness Test	155 power plant instrument technicians	Supervisor performance ratings	.27	.28	.01	Bosshardt, Rosse, & Peterson (1984)
FINGER DEXTERITY	Mechanical Math General Intelligence Table Reading Seven background, personality, and interest scales	O'Connor Tweezer Dexterity Test	155 power plant instrument technicians	Supervisor performance ratings	.27	.29	.02	Bosshardt, Rosse, & Peterson (1984)
MANUAL DEXTERITY	Wonderlic Personnel Test Bennett Mechanical Comprehension Test	Hand-Tool Dexterity Test	60 gas appliance service employees	Supervisory ratings	.67	.72	.05	Laney (1951)
	Wonderlic Personnel Test Bennett Mechanical Comprehension Test	Hand-Tool Dexterity Test	75 gas appliance service employees	Training school grades	.57	.62	.05	Laney (1951)
MULTILIMB COORDINATION	Math Table Reading Wheels	Rudder Control	90 foreign pilot trainees	graduation - elimination from pilot training	.47	.53	.06	Mullins, Keith, & Riederich (1968)
	24 paper-and-pencil measures	Rudder Control	90 foreign pilot trainees	Graduation - elimination from pilot training	.58	.64	.06	Mullins, Keith, & Riederich (1968)

Table 4 (Continued)

Construct	General Ability Test(s)	Psychomotor Test(s)	Sample	Criterion	Validity Results: General Ability Test(s) Only	Validity Results: All Tests	Validity Results: Incremental Validity	Reference
MULTILIMB COORDINATION (continued)	Air Force Officer Qualifying Test	Complex Coordination	62 Air Force Officer trainees	Graduation - elimination from undergraduate pilot training	.31	.56*	.25	McGrevy & Valentine (1974)
	Air Force Officer Qualifying Test	Complex Coordination	17 Air Force Officer trainees	Flying training deficiency elimination	.31	.52*	.21	McGrevy & Valentine (1974)
	Air Force Officer Qualifying Test	Complex Coordination	25 Air Force Officer trainees	Self-initiated eliminees from pilot training	.31	.56*	.25	McGrevy & Valentine (1974)

* average of 5 trials

Finally, incremental validity evidence was reviewed for each of five types of psychomotor abilities. The results indicated that measures of multilimb coordination may have some incremental validity when used in combination with general ability measures.

Feasibility of Adapting Psychomotor Tests to Computerized Administration

This section discusses the feasibility of adapting psychomotor tests with promising levels of validity (see Table 3) to computerized formats. Brief descriptions of these tests and the feasibility of adapting each measure to computerized administration are discussed below. The discussion is organized by psychomotor ability.

Arm-Hand Steadiness Tests

Two apparatus measures (Arm-Hand Steadiness Test, Steadiness Aiming Test) and one paper and pencil measure of arm-hand steadiness (Line Control) reviewed in the validity results section. All three measures had low validities with training and job proficiency criteria. Since none of these tests showed promising validity results, computerized adaptations of these measures will not be discussed.

Control Precision Tests

Three control precision tests (Target Tracking Test 1, Dial Setting Test, Pursuit Confusion Test) showed useful levels of validity. Brief descriptions of these tests are given below. (See the Appendix for detailed descriptions of these tests.)

Target Tracking Test 1. This is a computerized test that presents the examinee with a path of vertical and horizontal lines and target box with centered cross hairs. As the target box travels along the path, the examinee must use a joystick to keep the cross hairs centered on the target.

Dial Setting Test. This test consists of four dials with knobs and four corresponding stimulus apertures. The examinee's task is to set the four dials to the numbers shown in the apertures. When all four dials are set exactly to the numbers indicated, a new set of stimulus numbers is presented.

Pursuit Confusion Test. The apparatus test requires the examinee to keep a stylus on a variable speed target as it moves through a diamond-shaped slot. The entire target area is visible only by mirror vision.

Of these three control precision tests, Target Tracking Test 1 appears to be the most promising test. It is the only computerized control precision test and also has the highest median validity.

The Pursuit Confusion Test might also be adapted to a computer format. This could be accomplished by replacing the stylus with a joystick-controlled tracking device.

Finger Dexterity Tests

The three most promising tests of finger dexterity described earlier were the Purdue Pegboard, General Aptitude Test Battery--Finger Dexterity, and Crawford Small Parts Dexterity Test. Each test is described briefly below (see the Appendix for detailed descriptions).

Purdue Pegboard. This test requires examinees to insert pegs into holes on a wooden board and to assemble pegs, washers, and collars.

General Aptitude Test Battery--Finger Dexterity. This test has two subtests. One subtest involves assembling washers onto rivets and then inserting the assembled pieces into holes on a test board; the other subtest involves removing washers from rivets and then placing the rivets into holes on another board.

Crawford Small Parts Dexterity Test. This test involves using tweezers to pick up and insert pins into holes.

In general, all three finger dexterity tests require special apparatus (e.g., pegs, washers, collars, rivets, tweezers, pins) that would be difficult to adapt to a standard computer keyboard. Thus, none of these tests appears to be computer-adaptable.

Manual Dexterity Tests

Four measures of manual dexterity were found to have useful levels of validity. These were the Minnesota Rate of Manipulation, General Aptitude Test Battery--Manual Dexterity, Hand Tool Dexterity Test, and Stromberg Dexterity Test. Brief descriptions of these tests are given below (see the Appendix for detailed descriptions).

Minnesota Rate of Manipulation. This test requires examinees to manipulate a set of 60 blocks, either turning the blocks around or placing them in a different location.

General Aptitude Test Battery--Manual Dexterity. This test involves two tests similar to the Minnesota Rate of Manipulation that use pegs instead of blocks.

Hand Tool Dexterity Test. This test requires examinees to transfer bolt, washer, and nut units from one part of a test board to another using simple hand tools (wrench, screwdriver).

Stromberg Dexterity Test. This test requires examinees to transfer disks from one board to another as rapidly as possible.

In general, all four manual dexterity tests require manipulation of special apparatus (e.g., blocks, pegs, bolt/washer/nut units, disks). Each of these tests would be extremely difficult to adapt to a computerized format.

Multilimb Coordination Tests

Seven tests of multilimb coordination were found to have useful levels of validity. Two of these [Target Tracking Test 2, Complex Coordination (Sanders et al., 1971)] are computer tests and five [Bi-Manual Coordination Test, Rudder Control Test, Two-Hand Coordination Test, Complex Coordination Test (Melton, 1947), Two-Hand Pursuit Test] are apparatus measures. Each test is briefly described below. (See the Appendix for more complete descriptions.)

Target Tracking Test 2. This is a computer test that presents the examinee with a path of vertical and horizontal lines and a target box with centered cross hairs. As the target box travels along the path, the examinee must use two sliding resistors to keep he cross hairs centered on the target.

Complex Coordination Test (Sanders et al., 1971). This is a computer-administered test that requires the examinee to use a joystick to control the movement of an X-shaped stimulus while simultaneously using a foot-controlled rudder to control a short vertical line near the bottom of the display.

Bi-Manual Coordination Test. This apparatus test consists of a metal plate with a serrated pathway cut into the plate. The examinee's task is to move a vertical metal peg through the serrated pathway, controlling the peg movements by two metal bars that protrude from the apparatus.

Rudder Control Test. This test consists of a mock airplane device that measures the ability to simultaneously coordinate the movement of both feet.

Two-Hand Coordination Test. This apparatus test consists of a phonograph-like turntable, which has a mounted brass disk, that rotates along an irregular path at varying speeds. The examinee's task is to keep a metal leaf in continuous contact with this disk. The leaf's position is controlled by two rotating handles that can be manipulated simultaneously.

Complex Coordination (Melton, 1947). This apparatus test measures the ability to make coordinated movements using an airplane-type stick and rudder in response to patterns of visual signals.

Two-Hand Pursuit Test. This apparatus test consists of a bright metal target located inside a black box and superimposed against a movable black background. The examinee views the target and background through a tubular eye piece located on the top of the box and attempts to keep the moving target center directly beneath a small button by manipulating two handles.

Overall, the Target Tracking Test 2 appears to be the most promising of the multilimb coordination tests reviewed. It is a computer test and has the highest median validity of the tests considered. The Complex Coordination Test is another promising computer test that is currently being adapted to an Apple II computer with a joystick and foot pedal.[3]

Of the other multilimb coordination tests discussed, the Complex Coordination (Melton, 1947) and Two-Hand Coordination Test (Melton, 1947) have already been adapted to computer administration by Sanders et al. (1971). The Bi-Manual Coordination Test might be adapted to computer administration by using two joysticks in place of the metal bar controls. The Rudder Control Test and Two Hand Pursuit Test would be more difficult to adapt to computer testing.

Summary: Adaptability of Psychomotor Tests With Useful Levels of Validity to Computerized Administration

To summarize, the feasibility of adapting psychomotor tests with useful levels of validity to computerized formats was examined. The analysis suggested that good computer tests already exist for two psychomotor abilities: control precision (Target Tracking Test 1) and multilimb coordination (Target Tracking Test 2, Complex Coordination).

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[3] Norman G. Peterson, personal communication, October 1987.

No computer tests were found among the promising tests of finger dexterity or manual dexterity. All of these tests require special apparatus that would be extremely difficult to adapt to computer administration. Furthermore, although several computer tests have been or are currently being studied by military researchers, none of these tests measures finger dexterity or manual dexterity.[4]

Finally, no arm-hand steadiness tests were examined for computer-adaptability because all had low validities in previous studies.

SUMMARY AND CONCLUSIONS

This report evaluated the validity, incremental validity (over general ability), and feasibility of computerized administration of measures of five psychomotor abilities: multilimb coordination, manual dexterity, finger dexterity, control precision, and arm-hand steadiness. Several measures of each type of psychomotor ability were examined. A review of previous validity studies indicated that selected measures of four of the five psychomotor abilities have shown promising validities across jobs, training and other criteria. These abilities and their median validities are multilimb coordination (.27), manual dexterity (.20), finger dexterity (.19), and control precision (.17). The median validity for measures of the fifth psychomotor ability, arm-hand steadiness, was .05.

Evidence regarding the incremental validity of psychomotor tests over general ability was limited and mixed. Research on the incremental validity of individual psychomotor tests typically found only modest increases in validity, although the number of studies, predictors, and jobs examined was limited and the study sample sizes were typically small. Incremental validity evidence according to type of psychomotor ability indicated that measures of multilimb coordination may be most promising. Incremental validity results for combinations of psychomotor tests beyond general ability were also mixed. Hunter (1981, 1983) suggested that the incremental validity of psychomotor tests is moderated by job complexity, with psychomotor tests having greatest incremental validity when job complexity is low.

Finally, measures of multilimb coordination, control precision, finger dexterity, and manual dexterity with useful levels of validity were examined for adaptability to computerized administration. Computer tests with useful levels of validity were found for two psychomotor abilities--control precision and multilimb coordination. No computer tests were found for two other psychomotor abilities, finger dexterity and manual dexterity. In addition, finger dexterity and manual dexterity tests with high validities in previous studies do not appear to be adaptable to computer administration.

RECOMMENDATIONS

It is recommended that the Navy consider computerized psychomotor testing on an experimental basis using measures of two psychomotor abilities: multilimb coordination and control precision.

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[4]See footnote 3.

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APPENDIX

DESCRIPTIONS OF SELECTED PSYCHOMOTOR TESTS

DESCRIPTIONS OF SELECTED PSYCHOMOTOR TESTS

Arm Hand Steadiness (Melton, 1947)

Construct Measured: Arm Hand Steadiness

This apparatus test consists of a metal plate that has an aperture or hole and a metal stylus. The examinee's task is to hold the stylus within the aperture, minimizing the contact between the stylus and the edge of the aperture. The test consists of eight 30-second trials, each separated by a 15-second rest period. The test score is either the number of contacts or the amount of time the stylus is in contact with the edge of the aperture.

Bi-Manual Coordination Test (Melton, 1947)

Construct Measured: Multilimb Coordination

This apparatus test is intended to measure an individual's ability to coordinate dissimilar movements of the two hands. The test apparatus consists of a metal plate with a serrated pathway cut into the plate. The examinee's task is to move a vertical metal peg through the serrated pathway. The movements of the peg are controlled by two metal bars which protrude from the front of the apparatus. These bars must be operated simultaneously to control peg movement direction. The serrated pathways, which are on both sides of the pathway, trap the peg when erroneous movements are made. The test score is the distance traversed along the pathway.

Complex Coordination Test (Melton, 1947)

Construct Measured: Multilimb Coordination

This apparatus test is designed to measure the ability to make coordinated movements using an airplane-type stick and rudder in response to patterns of visual signals. The test apparatus consists of three double rows of lamps. One row of each pair of lamps has red lights (the signal row) and the other row has green lamps (the response row). When a pattern of lights is presented, the examinee must properly adjust the stick and rudder to match the pattern. After matching the pattern, a new pattern of signal lights is presented and the examinee must adjust the stick and rudder to match the new pattern. The test score is either the number of patterns matched in a fixed time period or the amount of time required to complete a given number of patterns.

Complex Coordination Test (Sanders et al., 1971)

Construct Measured: Multilimb Coordination

This is a computer-administered test. The examinee's task is to adjust a joystick to control the movement of an X-shaped stimulus while simul-

taneously using a foot-controlled rudder to control a short vertical line near the bottom of the display. Both stimuli make frequent, unpredictable changes in movement, partially under the control of a computer program. The examinee must attempt to keep the X-shaped stimulus centered at the intersection of the row and column of dots using a joystick and simultaneously keep the second stimulus aligned along the vertical row of dots with a rudder bar using both feet. The test consists of five 1-minute trials, and yields several scores: (1) horizontal deviation of the first stimulus from the target point (X Axis score); (2) vertical deviation of the first stimulus from the target point (Y Axis score); (3) square root of the sum of squares of the X Axis and Y Axis error scores (Generated score); (4) horizontal deviation of the second stimulus from the target point (Z Axis score); and (5) number of times the second stimulus moves off the screen (Reset score).

Crawford Small Parts Dexterity Test

Construct Measured: Finger Dexterity

This apparatus test consists of a 10-inch square board with 3 round wells for holding parts, a metal plate with 42 unthreaded and 42 threaded wells, 2 metal trays under the plate, tweezers, and a small screwdriver. In the first part of the test, the examinee uses a tweezers to pick up pins one at a time (using the preferred hand), inserts each pin into a small hole in the metal plate, and places a collar over it. The examinee does this for six rows of holes. In the second part of the test, the examinee picks up screws and begins threading the screw with the fingers, then finishes the threading using a screwdriver. In this part, both hands are used. The test score is either the time required to complete each part of the test or the number of holes filled for a given amount of time.

Dial Setting Test (Melton, 1947)

Construct Measured: Control Precision

This apparatus test consists of four dials with knobs and four corresponding stimulus apertures. The examinee's task is to set the four dials to the numbers shown in the apertures. When all four dials are set exactly to the numbers indicated, a new set of numbers is presented in the apertures. The test score is the number of settings completed within a given period of time.

Formboard Test (Farr et al., 1971)

Construct Measured: Manual Dexterity

This apparatus test consists of several blocks and forms. The examinee's task is to put the blocks or forms together to form different shapes. The test score is the number of seconds required to put the blocks or forms together.

General Aptitude Test Battery - Finger Dexterity (U.S. Dept. of Labor, 1952)

Construct Measured: Finger Dexterity

Assemble test - This apparatus test consists of a small rectangular board having 50 holes and a supply of small metal rivets and washers. The examinee's task is to pick up a metal rivet from a hole in the upper part of the board with the preferred hand and at the same time remove a washer from a vertical rod with the other hand. The examinee must then put the washer on the rivet and insert the assembled piece into the corresponding hole in the lower part of the board using the preferred hand. The score is the number of parts assembled during the time allowed.

Disassemble test - This apparatus test consists of a lower board having 50 rivets secured into holes with washers and a top board having 50 holes. The examinee's task is to remove the washer from the rivet of the assembly, place the washer on a vertical rod, remove the rivet from the hole, and then place the rivet in an empty hole in the top board. The score is the number of rivets and washers disassembled in the time allowed.

General Aptitude Test Battery - Manual Dexterity (U.S. Dept. of Labor, 1952)

Construct Measured: Manual Dexterity

Placing test - This apparatus test consists of a rectangular board divided into two sections; each section contains 48 holes (four rows of 12 holes). The holes on the upper section are filled with pegs. The examinee's task is to remove the pegs from the holes in the upper section and insert them in the corresponding holes in the lower section, moving two pegs simultaneously, one in each hand. The examinee is given three 15-second trials. The test score is the number of pegs removed from their holes during the three trials.

Turning test - This apparatus test consists of one board that has 48 pegs inserted into holes. The examinee's task is to remove a peg from the hole, turn the peg over so that the opposite end is up, and reinsert the peg in the hole from which it was taken using only the preferred hand. The examinee is given three 15-second trials. The score is the number of pegs turned during the time allowed.

Hand Tool Dexterity Test (Bennett and Fear, 1943)

Construct Measured: Manual Dexterity

This apparatus test consists of a wooden frame with two uprights attached to a horizontal baseboard and 12 bolt, washer and nut units of differing sizes. The examinee's task is to transfer bolt, washer and nut units from one part of a board to another using hand tools (a crescent wrench, end-wrenches, or a screwdriver). The method of performing the task is left to the [illegible]. The test score is the time taken to remove all sets of nuts

and bolts and washers from the right upright and fasten them onto the left upright.

Line Control (Mullins et al., 1968)

Construct Measured: Arm-Hand Steadiness

This paper-and-pencil test consists of a maze containing 80 small openings. The examinee's task is to trace through a series of openings in a maze pattern without touching the maze lines. The test score is the number of small openings traced without touching the maze lines in 1 minute.

Minnesota Rate of Manipulation Test

Construct Measured: Manual Dexterity

Turning test. This apparatus test consists of a large board having 60 holes and 60 cylindrical blocks. The examinee's task is to remove the blocks from the holes with one hand, turn the blocks over with the other hand and reinsert the blocks into the same holes as rapidly as possible. The test score is either the total time required for the examinee to turn all 60 blocks or the number of blocks turned within a given amount of time.

Placing test. This apparatus test consists of two boards, each containing 60 holes (four rows of 15 holes). The holes on one board are filled with blocks. The examinee's task is to place as many of the blocks into the proper holes on the second board as rapidly as possible. The test has two 40-second trials. The test score is either the total time required for the examinee to place all 60 blocks or the number of blocks placed within a given amount of time.

O'Connor Finger Dexterity Test

Construct Measured: Finger Dexterity

This apparatus test consists of a plate containing 100-3/16 inch holes and a metal tray containing 310 one-inch metal pins. The examinee's task is to place three pins in each hole as quickly as possible using only one hand. The examinee's score is the number of holes filled with three pins at the end of three minutes.

Peg Placing (Mathews & Jensen, 1977)

Construct Measured: Manual Dexterity

This apparatus test consists of a rectangular pegboard divided into two sections, each containing 48 cylindrical holes. Forty eight cylindrical pegs are placed in upper part of the pegboard. The examinee's task is to remove two pegs from the upper part of the pegboard, one in each hand, and place them in corresponding holes in the bottom part. The examinee is given three 15-second trials to remove as many pegs as possible. The test

score is the number of pegs successfully transferred by the examinee during the three trials.

Peg Turning (Mathews & Jensen, 1977)

Construct Measured: Manual Dexterity

This apparatus test consists of a rectangular pegboard divided into two sections, each containing 48 cylindrical holes. Forty eight cylindrical pegs are placed in upper part of the pegboard. The examinee's task is to remove one wooden peg from a hole and using only hand, turn the peg upside down and put it into the hole. The examinee is given three 15-second trials to turn as many pegs as possible. The test score is the total number of pegs successfully turned and replaced during the three trials.

Pennsylvania Bi-Manual Worksample

Construct Measured: Manual Dexterity

Assembly test. This apparatus test consists of an 8 x 24-inch board containing 100 holes arranged in 10 rows and a set of bolts and nuts. The examinee's task is to hold a nut between the thumb and index finger of one hand and a bolt between the thumb and index finger of the other hand, turn the bolt into the nut, then place both in a hole in the board. Twenty practice trials are allowed, and 80 trials are timed. The test score is the time to complete the task.

Disassembly test. This test uses the same apparatus described in the assembly test. The examinee's task is to disassemble the nuts and bolts. The test score is the time to complete the task.

Pinboard Test (Farr et al., 1971)

Construct Measured: Finger Dexterity

This apparatus test consists of a board with holes and several small pins. The examinee's task is to pick up the pins from a tray and stick them into holes on a board. The pins may be manipulated either by hand or using tweezers. The score is the number of pins placed into the board in a given amount of time.

Purdue Pegboard

Construct Measured: Finger Dexterity

This apparatus test consists of a wooden board with two rows of 25 holes into which pegs are inserted. At the top of the board are four trays containing pegs, washers, and collars. The test produces several scores which are briefly described below.

Right hand score. The examinee's task is to pick up one peg at a time from the tray with the right hand and insert the peg into one of the holes in the board. The test score is the number of pegs inserted in one 30-second trial.

Left hand score. The examinee's task is to pick up one peg at a time from the tray with the left hand and insert the peg into one of the holes in the board. The test score is the number of pegs inserted in one 30-second trial.

Both hands score. The examinee's task is to pick up two pegs at a time from the tray, one with the right hand and one with the left hand, and insert them into holes in the board. The test score is the number of pegs inserted in one 30-second trial.

Assembly score. The examinee's task is to assemble peg-washer-collar combinations as quickly as possible. The test score is the number of peg-washer-collar combinations assembled in one 30-second trial.

Summation score. This score consists of the sum of the four above scores.

Pursuit Confusion Test (Fleishman, 1956)

Construct Measured: Control Precision

This apparatus test requires the examinee to keep a stylus on a variable speed target as it moves through a diamond-shaped slot. The entire target area is visible only by mirror vision. The test score is either is the time-on-target during six 1-minute trials or the amount of time the stylus is in contact with the sides of the slot.

Rotary Pursuit Test (Melton, 1947)

Construct Measured: Control Precision

This apparatus test requires the examinee to keep a stylus in contact with a small metallic target while the target is rapidly revolving near the edge of a phonograph-like disk. The test score is total amount of time on target during five 20-second trials.

Rudder Control Test (Melton, 1947)

Construct Measured: Multilimb Coordination

This apparatus test consists of a mock airplane cockpit device. The examinee's task is to keep the cockpit directly lined up with one of three target lights as they come on in front of him/her. The examinee's own weight throws the cockpit off balance unless a proper correction is made using foot pedals. The examinee must also use the proper pedal control to shift the cockpit from one light to another as these come on at random intervals. The test score is total amount of time the cockpit is lined up with the proper light during three 112-second trials.

Santa Ana Finger Dexterity Test (Melton, 1947)

Construct Measured: Finger Dexterity

This apparatus test consists of a test board with square holes and 48 pegs having square bottoms and round tops. The top of each peg is half blue and half yellow. At the beginning of the test, the pegs are all turned so that the same color of each peg top is nearest the examinee. The examinee's task is to pick up each peg, turn it 180 degrees, and reinsert the peg into the hole. The test has five 35-second trials. The test score is the number of pegs turned and reinserted into the board during five trials.

Steadiness Aiming Test (Melton, 1947)

Construct Measured: Arm Hand Steadiness

This apparatus test consists of a stylus resting in a pivoted holder. The stylus handle extends down from the holder at a steep angle; the stylus tip is inserted inside a narrow hole. The examinee's task is to hold the stylus handle in such a manner that the stylus tip does not touch the sides of the hole. The test includes six 40-second trials. The test scores are the total number of contacts between the stylus and the sides of the hole and the amount of time the stylus is in contact with the sides the hole.

Stromberg Dexterity Test

Construct Measured: Manual Dexterity

This apparatus test consists of a tricolored form board with flat disks. The examinee's task is to transfer the disks as rapidly as possible in a designated order from one board to another. This is done twice. Each disk must be moved in a different manner from the other disks. The test score is the time taken to transfer all the disks. Testing time is 8 to 15 minutes.

Target Tracking Test 1 (McHenry, 1987)

Construct Measured: Control Precision

This is a computerized pursuit tracking test that uses a joystick. For each trial, the examinee is presented a path of vertical and horizontal lines. At the beginning of the path there is a target box with centered crosshairs. This target box travels along the path at a constant rate of speed. The examinee's task is to use a joystick to keep the crosshairs centered on the target. Over trials, the crosshairs, path length, target speed, and number of path segments vary. The test score is the mean distance from the center of the crosshair to the center of the target across 18 trials.

Target Tracking Test 2 (McHenry, 1987)

Construct Measured: Multilimb Coordination

This is a computerized pursuit tracking test measuring multilimb coordination. The test is similar to Target Tracking Test 1 except that the examinee must use two sliding resistors instead of a joystick to control the movement of the crosshair. One resistor controls vertical crosshair movement and the other resistor controls horizontal crosshair movement. The examinee's task is to keep the crosshairs centered on the target. Over trials, the crosshairs, path length, target speed, and number of path segments vary. The test score is the mean distance from the center of the crosshair to the center of the target across 18 trials.

Two-Hand Coordination (Melton, 1947)

Construct Measured: Multilimb Coordination

This apparatus test consists of a phonograph-like turntable which has a mounted brass disk. The disk rotates clockwise along an irregular path at varying speeds. The examinee's task is to keep a metal leaf in continuous contact with this disk. The leaf's position is controlled by two rotating handles. The handles can be manipulated simultaneously, so that the leaf can move in any direction along the top of the "turntable." The test has a fixed number of 1-minute trials separated by 15-second rest periods. The test score is the total time the leaf is in contact with the disk.

Two-Hand Coordination (Sanders et al., 1971)

Construct Measured: Multilimb Coordination

This is a computerized test that requires the examinee to use two joysticks to control the position of an X-shaped cursor shown on a video screen. The examinee's task is to maintain the position of the X as close as possible to a triangular target, which moves in a circular path at varying speeds. The target's velocity changes continuously throughout the test. The test has five 1-minute trials. The test produces three error scores: (1) horizontal deviation of the first stimulus from the target point (i.e., X Axis score); (2) vertical deviation of the first stimulus from the target point (i.e., Y Axis score); and (3) the square root of the sum of squares of the X Axis and Y Axis error scores (i.e., Generated score).

Two-Hand Pursuit (Melton, 1947)

Construct Measured: Multilimb Coordination

This apparatus test consists of a bright metal target located inside a black box and superimposed against a movable black background. The target and the background move in irregular paths at differing speeds. The examinee views the target and background through a tubular eyepiece located

on the top of the box. The examinee's task is to keep the target centered directly beneath a small button located at the intersection of a set of crosswires. Both the button and the crosswires are mounted at the center of the bottom of the eyepiece. The examinee controls the movement of the target by manipulating two handles, which can be manipulated simultaneously. The test consists of eight 1-minute trials. The test score is the total time the target is centered directly beneath the metal button.

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