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ABILITIES AT DIFFERENT STAGES OF PRACTICE IN ROTARY PURSUIT PERFORMANCE [1]

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In a number of previous studies Fleishman (1957a) and Fleishman and Hempel (1954, 1955) have shown that the particular combinations of abilities contributing to performance on psychomotor tasks may change as practice on these tasks continues. It has also been shown that these changes, when they occur, are progressive and systematic through the practice period until a point later in the learning period where they become stabilized. In other words, the particular combinations of abilities contributing to individual differences later in skill learning may be very different from those contributing early in learning.[2] The implications of these studies for predicting advanced levels of proficiency in psychomotor skills as well as to questions concerning the processes involved in the learning of such skills have been discussed earlier (Ferguson, 1956; Fleishman, 1956a; Fleishman & Hempel, 1955).

Contrary to earlier findings by Reynolds (1952) that the predictability of psychomotor performance decreases as a function of practice, our studies have indicated that such a decrease does not necessarily occur. In fact, it has been demonstrated (Adams, 1953; Fleishman, 1957a) that the amount of common variance between a practiced task and external measures may *increase* as practice continues, provided appropriate external measures have been included. Reynolds' study utilized only printed test measures. Our studies have shown that while certain printed measures may achieve a high degree of prediction of early psychomotor performance, psychomotor measures are better predictors of advanced levels on other psychomotor tasks. Moreover, the variance in common between different psychomotor tasks may actually increase as a function of practice on one or both of the tasks. Thus far, our general findings have been found to hold for a visual discrimination reaction task (Fleishman & Hempel, 1955), a complex serial reaction task (Fleishman & Hempel, 1954), and various other tasks of coordinated performances (Fleishman, 1956a, 1957a).

It is the purpose of the present study to evaluate possible changes in the aptitudes measured by the Rotary Pursuit Test (Melton, 1947) as practice on this task continues. It is safe to say that this task has been more

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[2] The term ability, as used here, refers to a more general, stable trait of the individual which may facilitate performance in a variety of different tasks. The term skill is more specific—it is task oriented. Thus, flying an airplane is a skill, while manual dexterity and spatial-visualization are more general abilities. Of course, abilities themselves are often products of earlier learning. This view has been elaborated elsewhere (Gagné & Fleishman, 1959).

widely used than any other single device in research on human motor learning. Yet, little is known about the nature of the abilities sampled by this task in terms of relationships with independently defined ability measures. It would appear important to establish what abilities are involved at different stages of practice on the task, especially if one is interested in the relationships between individual differences variables on the one hand and general laws of learning on the other. Moreover, definitions of ability variables involved in the performance of laboratory tasks in terms of external reference measures of such abilities may have relevance to the kinds of generalizations we may make from one task to another. Such "anchoring" of task variables in terms of abilities measured should assist in standardization and integration of "task variables" in more functional terms.

Method

Subjects

The *S*s were 224 basic trainee airmen at Lackland Air Force Base. Each *S* received extended practice (see below) on the Rotary Pursuit apparatus, and in addition received a carefully selected battery of printed and apparatus reference tests. These tests were thought to sample ability factors important at some stage of performance in Rotary Pursuit learning.

Half the *S*s received the reference tests before the practice task while the other half received the practice task first. Scheduling was arranged so that the printed tests were always administered to *S*s between the psychomotor reference tests and the practice task. In the administration of the psychomotor reference tests a rotational procedure was used in which the order of occurrence of each test in the series was fixed, but different *S*s started at different points in the series.

The Practice Task

The Air Force version of the Rotary Pursuit Test (CM803B2) hereafter referred to as RP, has been described fully by Melton (1947). The *S*'s task is to keep the tip of a prod-stylus in contact with a round, silver, metal target button set flush with the surface of a black Bakelite disc which rotates clockwise at 60 rpm. The black disc is .25 in. thick and 10.88 in. in diameter. The .75-in. silver target disc has its center located 3.19 in. from the center of the Bakelite disc. The hinged stylus is springloaded so that when it is held on the turntable with the handle and the rod in a straight line, a downward force of approximately 22 gm. is exerted on the silver contact tip.

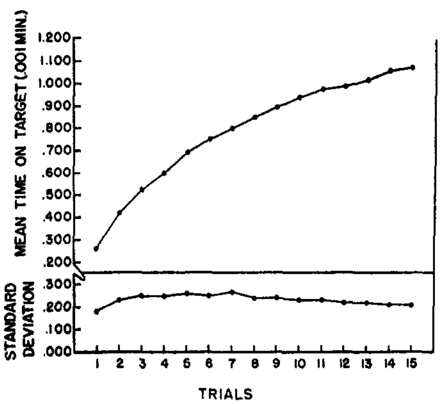

FIG. 1. Acquisition curve of performance on the Rotary Pursuit practice task.

The trials were administered with *S* in a standing position and the height of the turntable 38 in. above the floor. Four *S*s were tested at a time in a continuous session. Practice was continued through 15 trials, where each trial consisted in five 20-sec. test periods separated by 15-sec. pauses. Each of these trials (series of five 20-sec. test periods) was separated by a 30-sec. rest. Total score for a trial was the cumulated time (recorded on electric timers in .001 min.) *S* kept his stylus tip in contact with the metal target during the five 20-sec. test periods. Figure 1 presents the mean acquisition curve (and *SD*s) obtained for the 224 *S*s in the present study. It can be seen that after a slight initial increase, the group variability remains stable, with only a slight decrease in variability as practice continues. This is true even though the ceiling on performance imposed by the length of trial recorded was 1.667 min.

Brief descriptions of the printed and apparatus tests included in the study follow. Except where other references are given, more complete descriptions of the printed tests included may be found elsewhere (Guilford & Lacey, 1947). References for each apparatus test are given where available. The reliabilities of all these tests have been shown to be high in previous studies with comparable samples.

Printed Test Variables

General Mechanics, B1902B.—Verbally presented items require practical mechanical information dealing with the use and operation of familiar mechanical methods and devices.

Tool Functions, B1904A.—For each tool presented pictorially, *S* indicates how it is properly used.

Speed of Identification, CP610A.—Pictorial items are presented in which the silhouette of an object must be identified when it is rotated and imbedded in a group of highly similar silhouettes.

Instrument Comprehension, CI616C.—For each item, which presents views of cockpit instruments, *S* must determine the proper position or orientation of an airplane.

Visual Pursuit, BM802AXI.—From a series of mazes or irregularly curved lines, the task is to trace each line visually from its beginning to its proper termination point.

Aiming (*Fleishman, 1954, 1955*).—Make one dot in a series of very small circles ($\frac{1}{8}$ in. in diameter) working as fast and accurately as possible. Score is the number of dots correctly placed in two 30-sec. trials.

Marking Accuracy (*Fleishman, 1954*).—On a standard IBM answer sheet, fill in the one alternative slot per item which is circled, going from item to item as rapidly as possible. Score is the number of items completed minus errors in two 40-sec. trials.

Apparatus Test Variables

Purdue Pegboard-Assembly[3] (*Fleishman, 1954, 1955*).—A series of small peg-washer-collar-washer assemblies must be completed as rapidly as possible. Score is the number of assembly components completed in two 60-sec. trials.

Santa Ana Dexterity, CM116A (*Melton, 1947*).—A series of square pegs with larger circular tops must be lifted, rotated 180°, and replaced in their respective holes as rapidly as possible. Score is the number of pegs rotated in four 35-sec. trials.

[3] Distributed by Science Research Associates, 57 W. Grand Ave., Chicago, Ill.

Rate Control, CM825A (*Fleishman, 1958; Melton, 1947*).—A target line moves back and forth across a curved scale, with frequent changes in direction and rate of movement and *S* attempts to keep a pointer in coincidence with a thin line by adjustive manipulations of a knob control. Score is the cumulated time on target for four 1-min. trials.

Single Dimension Pursuitmeter, CM801B6 (*Fleishman, 1958; Melton, 1947*).—The *S* makes compensatory in and out movements of a control wheel, in order to keep a horizontal line in a null position as it deviates from center in irregular fashion. Score is the cumulated time "on target" for four 1-min. trials.

Rate of Movement (*Adams, 1953; Fleishman & Hempel, 1955*).—The task is to break the beams between a series of photoelectric cells, one after another, by making a series of gross, scalloped arm-hand movements as rapidly as possible. Score is the number of such movements completed in one 2-min. trial.

Rotary Aiming (*Fleishman, 1954, 1958*).—The task is to strike at a series of buttons arranged in a circular pattern on a horizontal panel going from one button to the next as rapidly as possible. Score is the number of strikes in four 30-sec. trials.

Jump Visual Reaction Time (*Fleishman, 1954, 1958*).—The *S* must move his hand six in. to strike a button as rapidly as possible in response to a single amber light before him. A click provides him with a ready signal before each light stimulus is presented with a foreperiod (between click and light) varying in a random order from .5 to 1.5 sec. Score is the cumulated reaction time for a series of 20 reactions.

Track Tracing (*Fleishman, 1954, 1958*)—The *S* is required to negotiate an irregular slot pattern with a T-shaped stylus held in the slot at arms length. Score is the number of errors (contacts with the sides of the slot) during six attempts.

Complex Coordination, CM701E (*Fleishman, 1958; Melton, 1947*).—The *S* makes complex motor adjustments of stick and pedal controls in response to successively presented patterns of visual signals. Score is the number of completed matchings in one 8-min. test period.

Discrimination Reaction Time, CP611D2 (*Fleishman, 1958; Melton, 1947*).—The *S* manipulates one of four toggle switches as quickly as possible in response to a series of visual stimulus patterns differing from one another with respect to the spatial arrangement of their component parts (e.g., position of a lighted red lamp relative to a lighted green

TABLE 1

INTERCORRELATIONS[a]

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1 Trial 1, RP																									
2 Trial 3, RP	82																								
3 Trial 5, RP	73	88																							
4 Trial 7, RP	72	84	90																						
5 Trial 9, RP	65	77	86	89																					
6 Trial 11, RP	65	74	83	86	88																				
7 Trial 13, RP	58	70	79	83	87	88																			
8 Trial 15, RP	54	64	74	80	82	84	85																		
9 General Mechanics	19	22	22	18	20	19	15	12																	
10 Tool Functions	19	22	18	16	17	14	13	07	71																
11 Speed of Identification	20	24	26	26	29	26	27	26	27	28															
12 Instr. Comprehension	20	22	22	20	21	25	20	23	47	42	45														
13 Visual Pursuit	30	33	25	23	23	24	22	21	23	27	32	32													
14 Aiming	27	32	34	29	32	30	27	29	12	08	22	18	11												
15 Marking Accuracy	26	33	33	31	34	35	38	34	14	05	39	19	28	31											
16 Purdue Pegboard Assembly	20	21	18	16	17	15	17	17	19	21	46	33	27	27	19										
17 Santa Ana	28	36	39	38	32	36	37	34	19	15	38	29	20	36	29	40									
18 Rate Control	25	25	19	21	18	17	12	19	16	10	08	05	19	04	12	07	12								
19 Single Dimension Pursuitmeter	23	22	18	21	20	17	18	18	07	04	16	14	11	02	13	09	16	52							
20 Rate of Movement	19	22	23	21	23	21	18	26	16	14	16	20	17	26	13	16	24	06	19						
21 Rotary Aiming	27	25	29	27	29	26	29	29	06	−01	25	13	23	23	32	27	31	13	20	32					
22 Jump Visual Reaction Time	24	24	26	24	22	19	18	25	04	−03	23	19	19	14	31	26	30	21	19	24	34				
23 Track Tracing	34	34	35	34	32	32	32	33	16	29	34	27	30	23	20	34	28	20	14	16	30	19			
24 Complex Coordination	37	36	34	35	32	31	35	39	29	33	39	47	38	19	28	34	38	21	21	20	24	28	38		
25 Discrimination Reaction Time	21	29	32	30	27	28	32	34	28	24	46	48	27	33	28	28	45	12	18	22	11	26	28	51	

[a] Correlations have been rounded from 3 places and decimal points omitted.

lamp). Score is the cumulated response time for a series of 20 stimulus settings.

RESULTS

Data analysis.—For each test the obtained distribution of raw scores were transformed to normalized distributions of standard scores (stanines), each with a range from 1 to 9, a mean of 5, and an *SD* of 2. Conversions were made so that the 9 end of the scale was always indicative of "good" performance (e.g., low reaction time, high time on target, high number of corrects). Pearson product-moment correlations between the tests and practice task trials were then obtained.

Eight stages of practice on the RP were selected for inclusion in the factor analysis together with the 17 reference tests described above. (The eight RP stages are Trials 1, 3, 5, 7, 9, 11, 13, and 15 represented in Fig. 1, where each trial consists in five 20-sec. practice periods). The intercorrelations among the 25 variables are presented in Table 1. Eleven factors were extracted from this matrix by the Thurstone Centroid Method (Thurstone, 1947). Factor extractions were continued beyond the point where any meaningful factor variance was suspected to be present. Table 2 presents the complete matrix of centroid factor loadings obtained. The distribution of residuals, after factor extraction, is symmetrical about zero and highly leptokurtic.

Orthogonal rotations of the axes defined by these factors were made using Zimmerman's Graphical Method (Zimmerman, 1946). Table 3 presents the orthogonal solution of rotated factor loadings obtained using the criteria of simple structure and positive manifold. Factors were interpreted for psychological meaningfulness from the projections of the reference tests on the rotated axes. Loadings of the stages of practice on RP on these factors were then examined.

Interpretation of factors.—The following interpretations are based on the factor loadings of the reference tests presented in Table 3. From the loadings of the first eight variables in this table, the reader can trace the importance of each factor at different stages of practice on the practice task.

Factor I is defined readily from its high loadings in the General Mechanics and Tool Functions Tests as the factor called *Mechanical Experience* in previous analyses (e.g., Fleishman & Hempel, 1954, 1955; Guilford & Lacey, 1947). It does not appear to contribute to individual differences in performance at any stage of practice on the RP task.

Factor II is not defined by any of the reference tests, but is confined only to the variables representing trials on the RP. Moreover, loadings of RP on this factor increase progressively through Trial 9, after which they remain at a relatively stable high level. The finding of a "within task" factor which increases in importance with practice, is consistent with our findings in parallel studies with other psychomotor tasks (Fleishman, 1957a; Fleishman & Hempel, 1954, 1955). For the present, this factor must be labeled RP Specific—I.

Factor III is also confined to performance on the RP. In contrast to Factor II this factor *decreases* progressively in importance from relatively high initial levels to near zero as practice continues. For the present we will refer to this factor as RP Specific—II.

Factor IV is identified primarily by the Rotary Aiming, Rate of Movement, and Jump Visual Reaction Time Tests. These tests are reference tests of a factor consistently identified as Speed of Arm Movement (Fleishman, 1954, 1957a, 1958; Fleishman & Hempel, 1954, 1955), defined simply as the speed with which an individual can make a gross arm movement. The other tests which load on this factor all emphasize simple rapid arm movements. The present study indicates that this factor contributes to individual differences in RP performance only at a very low to negligible level throughout practice on RP.

Factor V is identified from the loadings of the Discrimination Reaction Time, Instrument Comprehension and Complex Coordination Tests which have consistently been found saturated with a Spatial Orientation factor (Fleishman, 1954, 1957b; Fleishman & Hempel, 1954, 1956; French, 1951; Guilford & Lacey, 1947; Michael, Guilford, Fruchter, & Zimmerman, 1957). This factor seems to involve the ability to comprehend the arrangement of visual stimulus pattern, primarily with respect to *S*'s body as the frame of reference. Tests of this factor often ask "What position am I in, if the situation looks

TABLE 2

CENTROID FACTOR MATRIX[a]

	Factors											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	h^2
1 Trial 1, RP	70	33	−13	−18	−20	−18	−06	−06	−14	−02	02	75
2 Trial 3, RP	79	39	−06	−10	−21	−21	04	04	−16	−10	−04	91
3 Trial 5, RP	80	43	08	08	−19	−10	10	04	−10	02	−09	91
4 Trial 7, RP	80	48	13	10	−09	−07	03	08	−03	08	−09	93
5 Trial 9, RP	79	46	18	16	−06	08	−07	04	−01	06	04	91
6 Trial 11, RP	77	46	20	17	−01	04	−07	−06	−02	−07	05	89
7 Trial 13, RP	76	42	22	24	07	07	−17	−02	08	−07	−02	91
8 Trial 15, RP	75	38	16	25	14	09	−08	−16	07	05	−08	85
9 General Mechanics	42	−32	38	−38	−18	29	15	13	−07	−12	04	74
10 Tool Functions	38	−33	38	−48	−28	16	−03	09	09	−03	−06	75
11 Speed of Identification	53	−38	06	10	12	−10	−13	23	02	07	17	57
12 Instrument Comprehension	49	−40	28	−14	11	−07	07	−09	−08	13	14	55
13 Visual Pursuit	45	−21	−06	−17	06	−06	−22	−04	−16	−07	−06	37
14 Aiming	42	−11	−09	27	−20	−06	14	−09	10	−22	16	42
15 Marking Accuracy	48	−10	−10	20	16	04	−09	10	−14	−26	08	43
16 Purdue Pegboard Assembly	43	−38	−12	08	−08	−16	−11	13	16	14	08	46
17 Santa Ana Finger Dexterity	56	−21	−08	23	−04	−09	16	05	15	−04	−04	48
18 Rate Control	32	11	−34	−40	28	16	13	12	19	−02	−07	57
19 Single Dimension Pursuitmeter	34	09	−32	−26	31	17	19	04	15	13	13	49
20 Rate of Movement	37	−14	−13	09	−09	18	16	−24	−05	13	03	32
21 Rotary Aiming	43	−11	−36	20	−08	21	−15	−08	−09	15	03	48
22 Jump Visual Reaction Time	40	−14	−30	15	13	07	07	05	−19	12	−14	37
23 Track Tracing	51	−14	−05	−06	−05	−10	−22	−05	18	10	−08	39
24 Complex Coordination	60	−26	05	−13	20	−16	−06	−14	02	03	−15	54
25 Discrimination Reaction Time	55	−31	15	06	25	−23	29	−13	12	−09	−07	66

[a] Loadings have been rounded from three places and decimals omitted.

TABLE 3

ROTATED FACTOR MATRIX[a]

	Factors[b]											
	I ME	II Sp I	III Sp II	IV SAM	V SO	VI CP	VII RC	VIII P	IX FD	X Ai	XI R	h^2
1 Trial 1, RP	06	15	51	19	02	52	31	13	00	16	02	73
2 Trial 3, RP	14	32	60	16	07	48	31	19	02	24	−04	93
3 Trial 5, RP	12	50	58	25	07	38	25	10	07	16	−09	92
4 Trial 7, RP	08	61	51	22	04	39	27	12	13	06	−09	95
5 Trial 9, RP	12	65	36	24	−01	41	24	12	18	10	04	91
6 Trial 11, RP	05	68	31	16	04	45	20	06	16	20	05	90
7 Trial 13, RP	08	72	22	06	08	48	12	13	24	14	−02	92
8 Trial 15, RP	−03	64	13	20	17	49	20	09	26	09	−08	87
9 General Mechanics	81	14	03	−04	15	02	06	05	−05	12	04	73
10 Tool Functions	83	−01	08	−07	06	22	03	04	08	−02	−06	76
11 Speed of Identification	25	16	−01	14	32	02	00	45	33	02	17	55
12 Instrument Comprehension	41	11	−04	14	50	25	−07	15	03	−06	14	56
13 Visual Pursuit	20	−04	−06	10	22	36	11	28	02	16	−06	35
14 Aiming	11	08	25	12	23	10	−01	−03	35	36	16	44
15 Marking Accuracy	02	23	09	11	37	23	19	−01	02	40	08	47
16 Purdue Pegboard Assembly	12	−10	07	19	25	19	00	31	43	−05	08	45
17 Santa Ana Finger Dexterity	12	13	20	18	39	09	06	13	42	17	−04	49
18 Rate Control	01	−02	01	−05	17	01	72	06	10	−01	−07	57
19 Single Dimension Pursuitmeter	03	03	−04	−10	18	02	64	−07	06	−09	13	49
20 Rate of Movement	15	05	04	40	21	09	13	00	20	13	03	31
21 Rotary Aiming	−01	00	−05	53	00	09	18	00	27	22	03	45
22 Jump Visual Reaction Time	−03	03	−01	40	28	06	20	24	11	12	−14	39
23 Track Tracing	16	01	04	11	15	42	12	15	35	−04	−08	40
24 Complex Coordination	20	09	−01	09	46	44	13	18	14	02	−15	55
25 Discrimination Reaction Time	15	17	11	−03	72	19	03	05	19	08	−07	67

[a] Loadings have been rounded from three places and decimals omitted.
[b] Factors are identified as I, Mechanical Experience; II, RP, Specific I; III, RP, Specific II; IV, Speed of Arm Movement; V, Spatial Orientation; VI, Control Precision; VII, Rate Control; VIII, Perceptual Speed; IX, Finger Dexterity; X, Aiming; XI, Residual.

like this?" (or vice versa). The important role of this factor in many types of psychomotor performances has been explored elsewhere (Fleishman, 1957b). However, this factor makes no contribution to RP performance at any stage of practice.

Factor VI is the factor which has consistently been found common to the RP and Complex Coordination Tests, as well as to a number of other psychomotor tasks, in many previous analyses (Fleishman, 1954, 1958; Fleishman & Hempel, 1954, 1956; French, 1951; Guilford & Lacey, 1947). Until recently, the factor was called Psychomotor Coordination, defined rather broadly as representing coordination of the larger muscles of the body in movements of moderate scope. More recent studies (Fleishman, 1958; Fleishman & Hempel, 1956) were aimed at getting a more precise definition of this factor. The results indicated that this more general factor of psychomotor coordination splits into two broad factors. One of these (previously called Psychomotor Coordination I and then Fine Control Sensitivity) was common to tasks requiring highly controlled, larger muscle adjustments; the other (previously called Psychomotor Coordination II and then Multiple-Limb Coordination) was restricted to tests involving simultaneous coordination of responses of several limbs. The Complex Coordination Test was shown to measure both factors, but RP measured only the former. Hence, the present factor must be regarded as Psychomotor Coordination I. Support for this comes from the loading on this factor of Track Tracing, which measures error in making such highly controlled arm movements. The name which has finally evolved, as the definition of this factor became clarified through successive studies, is Control Precision.

This factor is of special interest since it has been shown that this is the main common factor measured by RP during a standard test period (represented by the first three trials in this study). The present study confirms this, and also indicates that this factor remains important in its contribution to individual differences in performance on RP at all stages of practice, although there is some dip in the contribution in the middle of the practice period.

Factor VII is defined very clearly by the Rate Control and Single Dimension Pursuitmeter Tests, both apparatus tracking tasks. The finding that performance on such tasks may involve a relatively independent common ability confirms previous findings (Fleishman, 1958; Fleishman & Hempel,

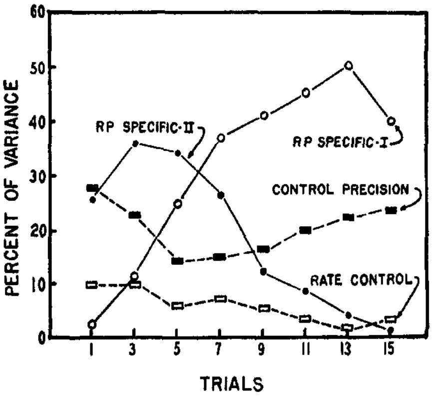

FIG. 2. Changes in the contribution of each factor to Rotary Pursuit performance as a function of practice.

1956). This factor, called *Rate Control*, appears to represent the ability to make continual anticipations and adjustments relative to changes in speed and direction of a continuously moving object. Also confirmed is the finding that this ability cuts across the traditional classification of "compensatory" versus "following" types of pursuit tasks. These results suggest that from the point of view of individual differences, this distinction of pursuit tasks may be arbitrary and the nature of these tasks may better be thought of in terms of this third underlying variable (here called Rate Control). Actually, this factor extends beyond pursuit tasks to other types of response involving rate (Fleishman, 1958; Fleishman & Hempel, 1956).

The loadings of RP on this factor are low, but the trends are highly consistent. Loadings drop progressively from .31 through Trial 3 to insignificant values late in practice.

Factor VIII is not well defined, but from the high loading of the Speed of Identification Test it appears to be the Perceptual Speed factor. Visual Pursuit, the other reference test of this factor has a loading of .28. Whatever the nature of this factor, it is clear that it does not contribute significantly to RP performance.

Factor IX is defined mainly by the two pegboard tests and is called Finger Dexterity. This ability involves facility in making rapid manipulations of small objects. Loadings of RP on this factor are generally negligible, although there is some trend for increasing loadings with practice. However, it appears, for the present, that Finger Dexterity makes no significant contribution to RP performance.

Factor X is defined by the two printed tests, Marking Accuracy and Aiming, which have defined an Aiming factor in previous studies (Fleishman, 1954; Fleishman & Hempel, 1954). This factor appears to be very narrow in score and not general to apparatus tests requiring aiming responses. RP does not load on this factor.

Factor XI is a residual factor.

Discussion

The RP task is of special interest since (*a*) it is one of the most commonly used devices for the study of human motor learning, (*b*) it is a pursuit task involving continuous movements, where our previous studies have involved more discrete choice-movement tasks, (*c*) it seems to be a less complex task in terms of the number of procedural problems involved, and (*d*) the initial factorial structure indicated it to be a more "pure" task. With regard to this latter point, it was of interest to note whether a relatively "pure" task would most resist changes in factor structure as a function of practice.

Figure 2 summarizes the percentages of variance contributed by those factors found in RP at each stage of practice. The estimates of percentages of common variance were obtained by squaring the individual factor loadings. These curves show the dramatic decrease in the importance of Factor III and the corresponding increase in Factor II as practice continues. Neither of these factors were definable by the external reference ability measures. The main factor measured by RP which was defined by external measures was the Control Precision factor and this contributed roughly 25% of the variance at late as well as early stages of practice. The factor called Rate Control contributes slightly (10%) early in practice but decreases steadily in importance.

The increase in importance of a factor common only to the task, itself, agrees with our findings with other kinds of psychomotor tasks (Fleishman, 1957; Fleishman & Hempel, 1954, 1955). This is consistent with the view that skill in later performance is more a function of specific habits acquired during practice on the task itself, relative to transfer from previous abilities, skills, and habits. While factors of *decreasing* importance have been found in other tasks, this is the first study in which such a factor was not defined by external ability measures. The nature of this decreasing factor is not immediately apparent. It is possible to speculate that this factor represents a "learning set" of some kind, which facilitates learning early but which drops out as a contributor as all *S*s gain experience with the task. Whatever explanation is adopted would have to account for the fact that we have not found this decreasing "within-task" factor in our studies with other motor tasks. We have already noted, however, that RP differs from previous tasks studied in its requirement for continuous movements, in its relative (initial) factorial "purity," and in its procedural simplicity. Whether any of these or other task characteristics are of consequence in relation to the decreasing "within-task" factor remains to be determined.

Perhaps, the most important result is the specification of the main source of variance RP performance has in common with other tasks. The Control Precision factor, which contributes at all stages of RP performance, has been found general to performance on a variety of different psychomotor devices. We may infer, then, that the main common ability sampled by RP is the ability to make highly controlled (but not overcontrolled), precise, large muscle adjustments. (Thus, the consistent "validity" of this test for predicting such complex performances as airplane piloting [Fleishman, 1956b; Melton, 1947] is "explained," even though there is little superficial resemblance between RP performance and piloting performance; both tasks tap the common ability of Control Precision.)

Another finding was the secondary contribution of a Rate Control factor early in practice, with a progressive decrease in importance of this factor through practice. This is consistent with what is observed in performing on RP, where the task seems initially to be more of a pursuit task; one has difficulty in leading the target properly and even in predicting where to move in relation to it. This difficulty seems to disappear after brief practice, where the task becomes one of minimizing erratic movements while making a smooth, continuous, circular arm movement.

A recent attempt to analyze the components of RP performance has been made by Ammons, Ammons, and Morgan (1958), using a micromation approach. They used motion picture recordings of performance, a rational classification of "types of movements," and a "scoring stencil" employed over the film frames at different stages of practice. Scores included the number and duration of circular, tapping, looping, reverse, and crisscross movements, as well as movements ahead of the target (leading) and behind the target (following). From this analysis they conclude that, "The *S* who can make the basic movement but whose timing is 'off,' is well on the way to a higher performance level, as compared with the *S* who cannot make the basic movement." This conclusion fits well with the present findings that (*a*) individual differences in Rate Control ability may facilitate early learning to a small extent, but this does not predict later learning; and (*b*) the main common factor contributing to advanced as well as early proficiency is Control Precision.

A completely different approach to the components of RP performance was made by Archer (1958). By inserting a mercury-puddle sensing device in the stylus he was able to measure the number and duration of "noncircular" movements to compare with "time-on-target" scores at different stages of practice. Archer's data show that number and duration of these "noncircular" movements decrease as practice continues. Archer does not provide a correlation between scores on this component at early stages of learning and "time-on-target" at later proficiency levels, but this would be highly relevant to our discussion. However, all three lines of investigation support the view that ability to make the proper controlled circular movement (even though one is off in his timing, and therefore off target, during early stages of learning) facilitates high later proficiency.

A final point relates to the high degree of specificity found in RP performance compared with other psychomotor tasks. The largest amount of RP variance in common with all the other tasks, at any stage of practice, was approximately 48% (the sum of squared loadings of all factors excepting the two "within-task" factors). This agrees very closely with previous communality estimates from factor analytic studies in which only single scores of RP were included. Communality estimates in six different studies (Fleishman, 1954, 1957a, 1958; Fleishman & Hempel, 1954, 1955, 1956) were all between .45 and .50. Estimates from the numerous earlier studies which included this test as part of the Aircrew Classification Battery (reported in Guilford and Lacey, 1947) were somewhat lower (.30–.40), which is reasonable since these batteries contained few psychomotor devices. On the other hand, it has been possible to account for more common variance in the case of several other psychomotor devices: 70% for the Complex Coordination task (Fleishman, 1957a; Fleishman & Hempel, 1954); 60% for the Discrimination Reaction Time Test (Fleishman, 1947a; Fleishman & Hempel, 1955); 58% for the Plane Control device (Fleishman, 1957a); and 66% for Unidimensional Matching (Fleishman, 1957a). The relative specificity of RP performance at least raises questions about the extent to which we can generalize from RP experiments to experiments with other tasks.

Experiments of the type described here suggest the hypothesis that what is improved, in learning, is in large measure something specific to the task. This, of course, does not preclude changes in common factors, also. Furthermore, it should be stressed that a factor's increase in importance does not necessarily mean an average gain in that ability. It means that a greater portion of individual differences can be accounted for by that factor. In the present instance, although individual differences continued to be a function of the more general Control Precision ability, increasingly, differences in performance were attributable to differences arising from specific experience with the task.

Summary

Extended practice was given 224 *S*s on the Rotary Pursuit apparatus. These same *S*s also received a battery of 17 reference ability measures. The intercorrelations were obtained among scores at eight stages of proficiency on the practice task together with the scores on the reference measures and these were subjected to factor analysis study. The results indicate that the main common factor identifiable from the reference tests and contributing to individual differences in RP performance, is the factor previously called Control Precision. This has been defined as the ability to make highly controlled, precise muscular adjustments. This factor contributed to RP performance at early as well as late stages of practice. The Rate Control factor contributed slightly to differences in early proficiency, but its contribution decreased with practice. Two major factors were not identifiable from the reference battery. One of these increased in importance as practice continued, while the other decreased steadily in importance. The increasing "within-task" factor has been found with other psychomotor tasks and may reflect the increasing importance of individual differences in the specific habits and skills acquired on the task itself. The hypothesis was advanced that the decreasing factor may reflect some kinds of "learning sets" which facilitate early learning, but not later learning.

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