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LEARNING AND MEASURED ABILITIES[1]

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The interrelationships among measures of learning and measures of abilities were investigated by administering a battery of ability tests and learning tasks to 102 6th-grade children. The learning tasks included concept-formation, paired-associate, and rote-memory tasks with verbal, numerical, and figural material. Ability scores and measures of learning were factor analyzed and 7 factors extracted. 1 factor was restricted to the ability measures; 3 were restricted to the learning measures; and 3 were common to both the ability and learning measures. It was concluded that performance in a learning task is related to measured abilities and to performance in other learning tasks and that there are learning factors which are not related to the abilities measured.

The first half of the twentieth century saw considerable interest in the relationship between learning ability and intelligence. Experimenters fairly consistently failed to demonstrate an association between them, however, so that we find statements to the effect that learning ability and intelligence are not the same thing (Guilford, 1940; McGeoch & Irion, 1952; Tyler, 1956; Woodrow, 1946). In addition, learning in one situation appeared to be unrelated to learning in other situations (Guilford, 1940; Husband, 1939, 1941).

These conclusions contradict everyday observation as well as the consistently high relationship found between intelligence and scholastic achievement and the established usefulness of ability testing for selection and prediction. Resolution of this contradiction depends first of all upon adequate measures of learning, and second upon the scope and nature of the learning situations and of the abilities measured.

Measures of learning ability which have been used include final level of attainment, gain (the difference between initial and final levels), and parameters of learning curves. Each of these is subject to more or less serious objections, including the effect of different initial levels, ceiling effects, unequal difficulty at different stages of learning, the choice of the functions to represent the learning process, and the number of parameters required by the function.

Two comparatively recent studies have investigated the relationship between learning and measured abilities using parameters of fitted learning curves. Both Stake (1961) and Allison (1960) found in factor-analytic studies that parameters of learning curves were related to ability and achievement measures and that there were additional factors common to more than one learning situation, but no general factor common to all.

Games (1962) also found that the learning of serial and paired-associate verbal tasks was related to measures of rote and span memory. Additional evidence of a relationship between

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learning and measured abilities is contributed in the area of motor tasks by Fleishman and Hempel (1954, 1955) and Fleishman (1960).

It is apparent, then, that abilities do contribute to performance in a learning situation. The principal difference between the present investigation and previous ones is an attempt to provide more adequate measures of learning performance and to systematically vary a small variety of learning tasks. The basic question is the relationship between measures of ability and measures of learning and between measures of learning in one task with those in other tasks.

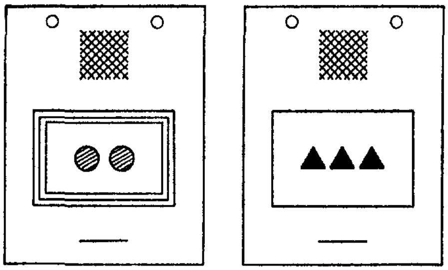

FIG. 1. Positive (left) and negative (right) instances of the concept "shaded" taken from the figural concept-formation task. (The correct response was printed on the back of each page behind the cross-hatched area.)

METHOD

Learning Tasks

Three types of learning tasks and three types of material were combined for a total of nine tasks. The types of task were concept-formation, paired-associates, and rote-memory; the types of material were verbal, numerical, and figural.

The concept-formation tasks were adapted from the Wisconsin Card Sorting task (Berg, 1948). Each task consisted of a series of stimuli printed one to a page, the pages being bound into a booklet. Each stimulus had four attributes which varied in three steps. For example the figural concept-formation task stimuli had one, two, or three borders; one, two, or three figures; the figures were either circles, squares, or triangles; and the figures were either white, shaded, or black. For each task one of the values of one of the attributes was chosen as defining positive instances of the concept. For the example given, the concept was "shadedness"; that is, all stimuli having a shaded figure or figures, whether they were circles, squares, or triangles and regardless of the number of borders, were positive instances of the concept.

The attributes and steps of the three concept-formation tasks are presented in Table 1. Figure 1 presents a positive and a negative instance of the concept "shaded." Twenty-five of the possible 27 positive instances and 25 negative instances were chosen and a block of 50 pages prepared. The sequence was random subject to the following restrictions: (*a*) the first stimulus was a positive instance, (*b*) there were five positive and five negative instances in each block of 10, and (*c*) no more than three positive or three negative instances occurred consecutively. The block of 50 stimuli was repeated twice for the figural task and three times for the verbal and numerical tasks to

TABLE 1

ATTRIBUTES AND STEPS USED IN CONSTRUCTING CONCEPT-FORMATION LEARNING TASKS

Concept formation—verbal		Concept formation—numerical		Concept formation—figural	
Attributes	Steps	Attributes	Steps	Attributes	Steps
Number of borders	1, 2, 3	Number of borders	1, 2, 3	Number of borders	1, 2, 3
Number of words	1, 2, 3	Type of border	Solid, sides only, corners only	Number of figures	1, 2, 3
Type of word[a]	Noun, verb[a], adjective	Number of numbers[a]	1, 2[a], 3	Type of figure	Circle, square, triangle
Type of print	All capitals, initial letters capitalized, all lower-case letters	Number of digits per number	1, 2, 3	Brightness of figure[a]	White, shaded[a], black

[a] The particular aspects defining positive instances of each concept.

TABLE 2
PAIRS USED IN PAIRED-ASSOCIATES LEARNING TASKS

Paired associates—verbal[a]		Paired associates—numerical[b]		Paired associates—figural	
Stimulus	Response	Stimulus	Response	Stimulus	Response
YAT	jewel	POLEF	63	1	□
TIS	dinner	GOKEM	95	2	ω
ZUG	money	LATUK	57	3	+
KEM	village	ZUMAP	89	4	>
SOZ	insect	TAROP	31	5	Δ
NOL	wagon	BALAP	18	6	χ
RUH	office	KUPOD	76	7	∘
BEK	kitchen	MEDON	42	8	-
				9	γ
Example pairs					
JAX	uncle	NARES	71	A	/
ZAD	leader	CAROM	47	B	*
WIQ	zero	FIMUR	90	C	λ

[a] Pairs selected from list used by Martin and Saltz (1963).
[b] Paralogs selected from Noble (1953); numbers from random number table.

make booklets of 100 and 150 pages, respectively.

At the bottom of each page was a line on which the subject was instructed to mark a plus (+) if he thought the stimulus was "correct" or a zero (0) if he thought it was "wrong." He then turned the page and checked his answer against the correct answer printed on the back of the page. On the last page of the booklet he was asked to write the basis for his responses, to verbalize the concept, if he could.

The instructions to the subjects stated that they would be guessing at first, but that as they went along, they should be able to get more and more correct answers, and that they were to try to get as many correct as possible. A subject's learning performance was scored in terms of the number of correct responses for successive blocks of 10 stimuli.

Table 2 presents the pairs used in the paired-associate learning tasks. All three tasks were presented in modified teaching machines using the anticipation method. Thus the subject turned the knob of the machine until the stimulus member of a pair appeared in the opening of the machine. If he knew the response member of the pair, he wrote it on the paper, then advanced the paper so that the stimulus and the subject's response moved under a plastic window and the correct response appeared in the opening. The experimeter set the pace, telling the subjects when to turn to the stimulus, etc. Approximately three seconds were allowed for the stimulus members of the numerical and figural tasks and four seconds for the verbal task in order to provide time for the subjects to write their responses. Approximately two seconds were allowed for the response members of all pairs. Each set of pairs was presented 15 times in different, randomized order, with approximately 10 seconds between repetitions. The subject's score was the number of correct anticipations on each repetition after the first presentation.

The lists used in the verbal and numerical rote-memory tasks are given in Table 3. The lists were each presented 12 times in the same order, at a rate of approximately one word or number every two seconds, with approximately 10 seconds between presentations. Each presentation was followed by a free-recall test. A subject's score was the number of words or numbers recalled correctly on each test, without regard to order of recall.

In the figural rote-memory task, 16 nonsense figures were presented for study for 15 seconds. Immediately following the study was a recognition test in which 16 groups of five nonsense figures were presented, each group containing one of the original figures. The study and test were repeated 12 times, and a subject's score was the number of figures correctly identified on each test.

Ability Tests

The abilities selected for measurement were chosen on the basis of a priori judgment of relevance and the availability of suitable tests. The tests, taken from the Kit of Reference Tests for Cognitive Factors by French, Ekstrom, and Price (1963), were:

Ma: Associative Memory (3 subtests)
Ms: Memory Span (2 subtests)
N: Number Facility (3 subtests)
P: Perceptual Speed (3 subtests)
R: General Reasoning (2 subtests)
V: Verbal Comprehension (2 subtests)

Also included as measures of ability were a Kuhlman-Anderson intelligence score and scores on six subtests of the Stanford Achievement Battery (SAB). The six subtests were:

SAB–PM: Paragraph Meaning
SAB–WM: Word Meaning
SAB–SP: Spelling
SAB–LA: Language
SAB–AR: Arithmetic Reasoning
SAB–AC: Arithmetic Computation

Subjects

The entire sixth grade (135 students in five different classrooms) of an urban New Jersey school participated in the study. Complete information was obtained for 102 children, and all analyses are based upon only those 102.

Procedure

The learning tasks and ability tests were administered in eight sessions, each approximately one hour long. The sessions occurred in the mornings and afternoons of four consecutive days. They were administered in the regular classrooms by psychology graduate students. The distribution of tasks and tests within sessions was determined randomly with the restriction that no learning tasks of the same type or material and no tests of the same ability were included in the same session. There was one exception to this rule; the two memory-span subtests were prerecorded and, to avoid the use of five tape recorders on two days, were administered as the first and last tests of the same session.

In scoring the learning tasks, liberal standards were used with regard to spelling.

TABLE 3

LISTS OF WORDS AND NUMBERS USED IN VERBAL AND NUMERICAL ROTE MEMORY LEARNING TASKS

Rote memory—verbal[a]	Rote memory—numerical[b]
MODERN	83
PRETTY	60
GOLDEN	94
FAMOUS	97
GENTLE	13
BETTER	48
COMMON	92
SIMPLE	78
HAPPY	56
NARROW	52
HEAVY	43
LITTLE	36

[a] AA, 2-syllable adjectives from Thorndike & Lorge (1944).

[b] From random number table.

In addition, in all cases where appropriate, the students were told that there was no penalty for guessing, that if they thought they knew an answer but were not sure to go ahead and mark it.

Analysis

Each learning task was scored in terms of the number of correct responses in successive blocks or trials. The Subjects × Trials matrix for each task was analyzed separately according to a method developed by Tucker (1960). The characteristic roots and vectors of the crossproduct matrix formed from the raw score matrix were found and a decision made as to how many were significant.

The factor scores or coefficients of the subjects on these unrotated factors were then calculated. The scores obtained in this way indicate the contribution of each component to each person's performance in that particular learning situation. In other words, the first step determines how many factors are involved in learning a given task; the second step determines the importance or weight of each for a given individual. The scores for the individual were assumed to describe his learning performance.

The individual's scores on all of the learning tasks were then combined with his achievement and ability scores, and the resulting correlation matrix was factor analyzed. Seven factors were extracted, and rotated to an equamax solution.

RESULTS

Learning Tasks

Figure 2 presents the learning curves averaged across the 102 subjects for each task. Learning was not as complete as desirable for the concept-formation tasks, and the number of correct verbalizations of the concepts was correspondingly small, being 20, 41, and 26 for the verbal, numerical, and figural tasks respectively. Learning in the other tasks appears satisfactory.

An indication of the reliability of the factor scores on the learning tasks is provided by the final communality estimates determined by an iterative, refactoring procedure. These estimates provide a lower bound for the reliability and are presented in Table 4. Those for the first component of each task are reasonably high, comparing favorably with those of the ability tests. Those of components after the first are lower, indicating either lower reliability or greater specificity of the component.

Ability Tests

The ability tests were difficult for the subjects, the sixth grade being the lower limit of the range recommended for the tests. Corrected split-half reliabilities and final communality estimates for the ability measures are presented in Table 5.

Learning and Reference Factors

The loadings of the learning-task components and the ability measures on each of the seven factors rotated to an equamax solution are presented in Table 6. The factors were interpreted as follows:

Factor I: Verbal ability. The first factor is interpreted as a verbal-ability factor, and it is common to both the learning tasks and the ability measures.

Factor II: Reasoning ability. All of the reasoning tests have their highest loadings on this factor, and the figural paired - associates and rote - memory tasks have high loadings on it. The verbal and numerical tasks do not.

Factor III: Speed. The common element of the variables loading on this factor seems to be that they involve simple operations which almost everyone can do correctly, given enough time. Accordingly, it is called a speed factor. It is apparently not useful in describing performance in the learning tasks.

Factor IV: Rote-memory ability. This factor is involved in the three associative-memory subtests and in all of the paired-associate and rote-memory learning tasks except figural rote memory. It is interpreted to be a rote-memory factor common to both the ability measures and the learning tasks.

Factor V: Nonverbal learning. This factor is primarily defined by rote-memory tasks involving either numbers or figures. It is interpreted as a nonverbal rote-learning factor distinct from the ability measures.

Factor VI: Concept formation. All of the concept-formation tasks load on this factor and on no other, and no other variable has an appreciable loading on it. Concept formation as defined by the tasks used is not related to the abilities measured or to the other learning tasks.

Factor VII: Verbal learning. This factor is defined primarily by learning tasks involving verbal material. It is interpreted as a verbal learning factor, independent of the abilities measured.

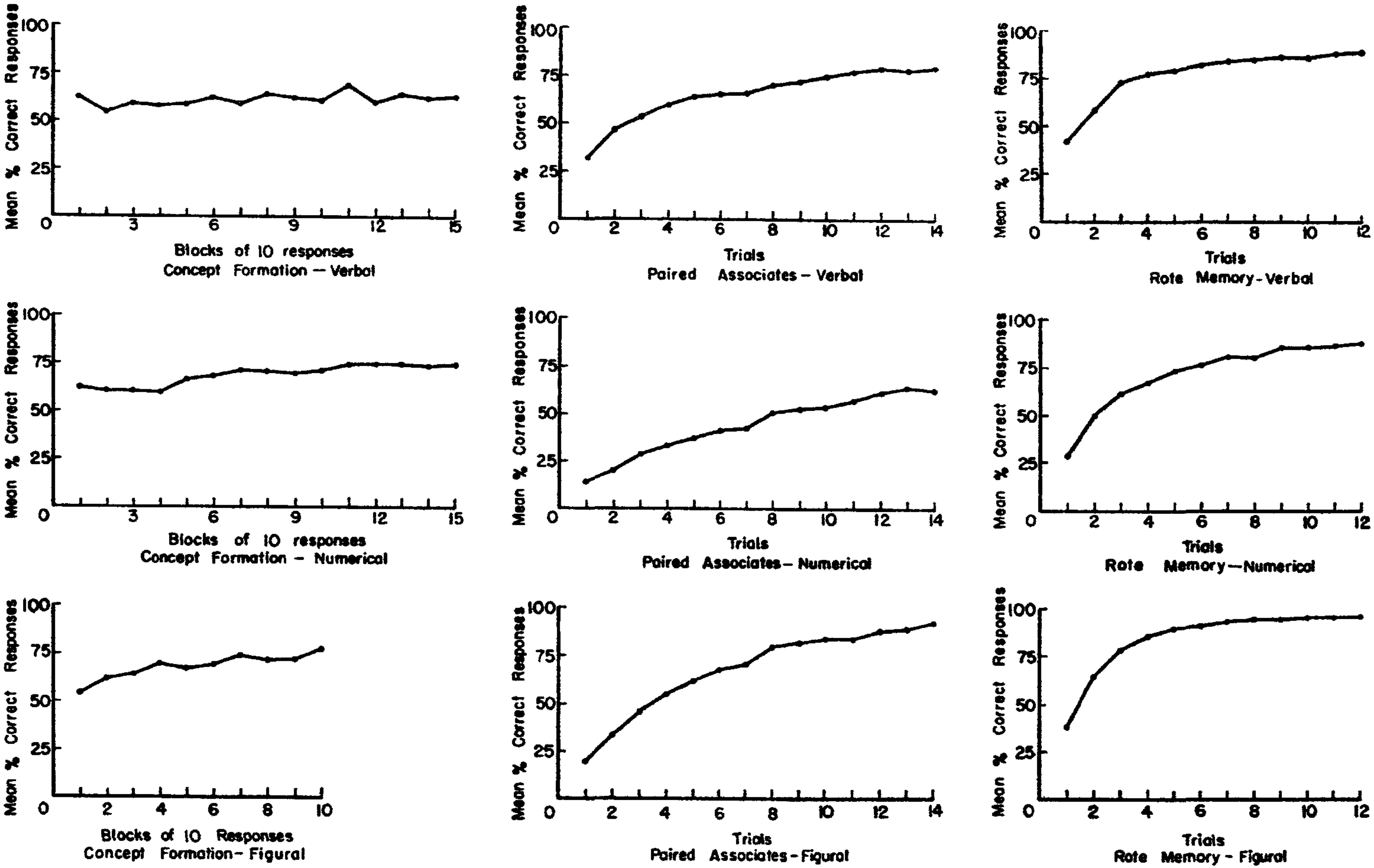

FIG. 2. Trial means expressed as percent of total possible correct responses for each of the nine learning tasks.

TABLE 4
FINAL COMMUNALITY ESTIMATES FOR LEARNING VARIABLES

Variable	Communality
CF-V-1	.34
CF-V-2	.11
CF-V-3	.19
CF-V-4	.04
CF-N-1	.48
CF-N-2	.12
CF-N-3	.16
CF-F-1	.43
CF-F-2	.04
PA-V-1	.55
PA-V-2	.22
PA-V-3	.25
PA-N-1	.60
PA-N-2	.33
PA-N-3	.07
PA-F-1	.46
PA-F-2	.43
PA-F-3	.17
RM-V-1	.57
RM-V-2	.30
RM-V-3	.18
RM-N-1	.51
RM-N-2	.28
RM-F-1	.60
RM-F-2	.37
RM-F-3	.37

Note.—The numbers following the learning task designation indicate the component curves for that task. For example, CF-V-1 is the first component curve of the verbal concept-formation task.

DISCUSSION

In a factor-analytic study, only those dimensions will be revealed along which there is variation in both the variables and the subjects. The generality of the findings is thus restricted by the sampling of measures and people. In this study the sample of subjects is assumed to be representative of the population of sixth-grade children from urban public schools. The sampling of learning tasks and ability measures was, on the other hand, intentionally restricted. It is possible, however, to draw some interesting conclusions regarding the relationships between learning and abilities and learning in different situations.

In the first place, learning is related to measured abilities. With the exception of the concept-formation tasks every learning task was related to one or more of the abilities measured. Furthermore, the abilities were in general appropriate to the a priori classification of the tasks. More specifically, tasks involving words had loadings on verbal factors; tasks involving numbers and figures loaded on nonverbal factors; and paired-associate and rote-memory tasks had loadings on memory factors.

The conclusion that learning and

TABLE 5
RELIABILITIES AND COMMUNALITIES FOR REFERENCE VARIABLES

Variable	Reliability	Communality
IQ	.87[a]	.70
SAB-PM	.90[a]	.82
SAB-WM	.92[a]	.78
SAB-SP	.93[a]	.67
SAB-LA	.81[a]	.58
SAB-AR	.89[a]	.68
SAB-AC	.87[a]	.59
Ma-1	.76	.42
Ma-2	.79	.46
Ma-3	.81	.73
Ms-1	.58	.31
Ms-3	.68	.57
N-1	.91	.73
N-2	.92	.64
N-3	.90	.73
P-1	.81	.29
P-2	.79	.42
P-3	.88	.49
R-1	.44	.50
R-4	.44	.43
V-1	.62	.58
V-2	.68	.42

[a] Reliability coefficients marked taken from the test manual. Coefficients not marked are split-half coefficients corrected for full length with the Spearman-Brown formula.

TABLE 6

ROTATED FACTOR MATRIX

Variable	Factor						
	I	II	III	IV	V	VI	VII
IQ	47	52[a]	40	06	15	15	03
SAB-PM	69[a]	48	28	06	−06	08	13
SAB-WM	77[a]	37	17	03	−07	00	13
SAB-SP	55[a]	24	39	25	20	−04	25
SAB-LA	69[a]	22	15	13	07	08	10
SAB-AR	42	59[a]	34	12	07	04	12
SAB-AC	28	51[a]	40	−11	16	22	09
Ma-1	09	10	18	54[a]	22	08	17
Ma-2	19	17	04	60[a]	14	04	13
Ma-3	33	14	27	51[a]	27	−08	44
Ms-1	44[a]	06	−03	−12	24	18	03
Ms-3	63[a]	−25	05	09	22	17	−17
N-1	26	23	77[a]	−01	11	04	06
N-2	15	32	59[a]	22	32	06	−03
N-3	19	03	80[a]	15	15	06	−06
P-1	01	19	30[a]	16	23	28	−09
P-2	10	06	56[a]	16	18	16	11
P-3	10	46[a]	41	20	04	14	−18
R-1	34	55[a]	12	−05	08	−01	23
R-4	29	48[a]	24	17	04	−03	17
V-1	63[a]	26	17	03	−24	02	18
V-2	55[a]	21	23	06	−11	07	−06
CF-V-1	13	05	−02	−05	15	52[a]	14
CF-V-2	09	11	21[a]	−08	07	12	15
CF-V-3	17	−01	−21	16	−08	25[a]	−14
CF-V-4	04	−02	−03	16[a]	06	03	−05
CF-N-1	−07	14	−04	08	−10	66[a]	09
CF-N-2	−07	−10	−18	−04	06	−25[a]	−06
CF-N-3	−14	08	−03	−03	−25[a]	16	19
CF-F-1	−06	−23	03	06	07	58[a]	17
CF-F-2	−01	04	18[a]	01	00	−09	04
PA-V-1	40[a]	25	22	30	12	24	34
PA-V-2	−26	−02	03	−01	−09	−23	−31[a]
PA-V-3	−25	−17	−13	−26[a]	−21	05	18
PA-N-1	−03	24	01	39	37	16	48[a]
PA-N-2	09	10	−04	−53[a]	04	−11	14
PA-N-3	02	07	05	−03	02	−05	−25[a]
PA-F-1	−04	33	15	43[a]	27	22	17
PA-F-2	−15	27	−06	51[a]	20	13	−08
PA-F-3	03	14	−18	−01	−22[a]	−16	−21
RM-V-1	39	13	34	18	01	07	49[a]
RM-V-2	04	10	16	49[a]	−12	−07	10
RM-V-3	04	−02	−01	18	09	−09	−36[a]
RM-N-1	−02	16	21	33	57[a]	03	08
RM-N-2	−06	−04	08	25	42[a]	03	−15
RM-F-1	03	64[a]	03	01	44	05	−03
RM-F-2	00	55[a]	03	22	−01	09	−07
RM-F-3	−06	08	02	−15	57[a]	01	10

Note.—Decimals are omitted.

[a] The highest loading for a variable.

measures of abilities are related is not new, having been reached both in the field of motor tasks (Adams, 1957; Fleishman, 1960; Fleishman & Hempel, 1954, 1955) and in the field of cognitive tasks (Allison, 1960; Games, 1962; Stake, 1961). The present results are corroborative of these previous findings and extend their generality to learning tasks more representative of those found in other psychological literature.

The second conclusion is that there are learning factors which are independent of the abilities measured. Three such factors were found: The concept-formation factor and the verbal and nonverbal learning factors.

Both Stake (1961) and Allison (1960) also found learning factors, but in neither case did the factors distinguish between verbal and nonverbal tasks. Games (1962) also found two or possibly three remaining factors after rote- and span-memory factors had been partialed out of the learning performances, but he did not interpret them as learning factors.

That the distinction between verbal and nonverbal learning factors is neither obvious nor trivial is indicated both by its failure to appear in the studies cited and by the distinctions which were possible but which did not occur in the present study. For example, the paired-associate and the rote-memory tasks did not define separate factors; nor did the numerical and figural materials separate.

It is possible that the learning factors represent abilities which were not included in these measures, but because of the regularity with which factors additional to ability factors seem to be found, it seems unlikely that adding new ability measures will eliminate them. Rather it seems that there are processes involved in active, repetitive learning situations which are independent of the abilities which can be measured in a static testing situation. Interest and motivation might be contributing factors. Gaudry and Champion (1962) have suggested that anxiety (as measured by the Taylor Manifest Anxiety Scale) affects the limit of learning.

The third major conclusion is that learning in one situation is related to learning in others. In other words, while there does not appear to be a general learning factor, it does appear that there are fewer learning factors than learning tasks. This intertask relationship exists both in the ability and learning factors. Each task loads on a unique combination of factors, but the factors are common to other tasks.

The fourth and final conclusion is that the concept-formation tasks used are unrelated to the other learning tasks and to the abilities measured. It is not clear why this should be so. One possibility is that the tasks called concept formation are rather specialized tasks requiring fairly specific abilities which may or may not be the same as those required in the usual scholastic or intellectual tasks thought of as "concept formation." That is, whether the lack of interrelationships lies in the battery of ability tests or in the specially devised learning tasks or both remains at present a puzzle.

REFERENCES

ADAMS, J. A. The relationship between certain measures of ability and the acquisition of a psychomotor criterion response. *Journal of General Psychology*, 1957, 56, 121-134.

ALLISON, R. B. Learning parameters and human abilities. Office of Naval Research Technical Report. Princeton, N. J.: Educational Testing Service, 1960.

BERG, E. A. A simple objective technique for measuring flexibility in thinking. *Journal of General Psychology*, 1948, 39, 15-22.

FLEISHMAN, E. A. Abilities at different stages of practice in rotary pursuit performance. *Journal of Experimental Psychology*, 1960, **60**, 162–171.

FLEISHMAN, E. A., & HEMPEL, W. E., JR. Changes in factor structure of a complex psychomotor test as a function of practice. *Psychometrika*, 1954, **19**, 239–252.

FLEISHMAN, E. A., & HEMPEL, W. E., JR. The relation between abilities and improvement with practice in a visual discrimination reaction task. *Journal of Experimental Psychology*, 1955, **49**, 301–312.

FRENCH, J. W., EKSTROM, R. B., & PRICE, L. A. *Kit of reference tests for cognitive factors*. (Rev. ed.) Princeton, N. J.: Educational Testing Service, 1963.

GAMES, P. A. A factorial analysis of verbal learning tasks. *Journal of Experimental Psychology*, 1962, **63**, 1–11.

GAUDRY, E., & CHAMPION, R. A. The identification of learning-curve parameters with intelligence and motivation. *Australian Journal of Psychology*, 1962, **14**, 87–93.

GUILFORD, J. P. Human abilities. *Psychological Review*, 1940, **47**, 367–394.

HUSBAND, R. W. Intercorrelations among learning abilities: I. *Journal of Genetic Psychology*, 1939, **55**, 353–364.

HUSBAND, R. W. Intercorrelations among learning abilities: IV. Effect of age and spread of intelligence upon relationships. *Journal of Genetic Psychology*, 1941, **58**, 431–434.

MARTIN, C. J., & SALTZ, E. Serial versus random presentation of paired-associates. *Journal of Experimental Psychology*, 1963, **65**, 609–615.

MCGEOCH, J. A., & IRION, A. L. *The psychology of human learning*. (2nd ed., revised by A. L. Irion) New York: Longmans, Green, 1952.

NOBLE, C. E. The meaning-familiarity relationship. *Psychological Review*, 1953, **60**, 89–98.

STAKE, R. E. Learning parameters, aptitudes, and achievements. *Psychometric Monographs*, 1961, No. 9.

THORNDIKE, E. L., & LORGE, I. *The teacher's word book of 30,000 words*. New York: Teachers College, Columbia University, 1944.

TUCKER, L. R. Determination of generalized learning curves by factor analysis. Office of Naval Research Technical Report. Princeton, N. J.: Educational Testing Service, 1960.

TYLER, L. E. *The psychology of human differences*. (2nd ed.) New York: Appleton-Century-Crofts, 1956.

WOODROW, H. The ability to learn. *Psychological Review*, 1946, **53**, 147–158.

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