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A Principal Component Analysis of the Relationship between Certain Measures of Non-motor Abilities and the Two Different Learning Indices on a Mirror Drawing Task

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Two different learning indices of a Mirror drawing task (speed, accuracy) were analyzed with reference tests by using principal component analysis. The results indicated the following:

a) The component structures of the two learning processes were similar to each other in early stages of practice, but not in the latter stages.
b) A non-motor component related positively to the "accuracy" learning process, while it related negatively to the late stages of "speed" learning.
c) A high Score Group on the non-motor component was significantly superior to a Low Score Group during the early and middle stage of "accuracy" learning. On the other hand, the Low Score Group tended to be significantly superior to the High Score Group in the latter stages of "speed" performance.

It would appear that in the acquisition of some skills, learning might be characterized by a multiple process and not simply a single process. Also specific abilities are related to each learning process in currently undefined ways.

In previous factor analytic studies (Fleishman 1954–60. Hinrchs 1970, & Inomata 1971), the relationship between abilities and the skill learning has been discussed as an essential problem in the acquisition of skills. Generally speaking, it seems to have been justified that the structure of components changes during learning process. Usually, these studies have employed one task as a practice task and some battery of tests as reference tests to interpret the factors which contribute to the learning process. However, when the learning process is analyzed, it should be asked whether or not the learning process is single or multiple, because the selection of the index of learning is based on this problem.

In a recent report Fleishman and Fruchter (1967) proposed a new design in which multiple measures of performance were employed. The factor analysis on their new design yields factors which represent the relationships between trials not only for a single measure but also over different measures. Therefore, this model might be an effective instrument to determine whether or not the learning process is multiple, or not.

In the present study this design was employed using reference tests in order to examine (a) the relationship between two different learning indices of a mirror drawing task during practice, (b) how non-motor components relate to the different learning processes, and (c) the related

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hypothesis that if the non-motor components play a role in each process, the individual differences on the components have a certain effect on the performance in each process.

METHOD

Subject

The Ss were 51 junior high school students (male, Age 13) in Shizuoka, JAPAN. No Ss had prior experience of the tests.

Reference tests

Six printed tests were administered as reference tests in order to measure non-motor abilities which aimed primarily at visual and space perception. The battery of tests were based on Thurston's (1940) and Koga's (1935) factor analytic studies. The pretest battery was administered to the subjects two weeks before the experiment of practice task. All of the tests used were paper and pencil tests.

Test 1. Eye measuring test
Test 2. Visual pursuit test
Test 3. Identical number-order test
Test 4. Coding test
Test 5. Copying test
Test 6. Block-counting test

Practice task

A mirror drawing apparatus described by Candland (1968) was used in the present experiment.
Ss received 15 trials with 30 seconds rests between trials. Ss were instucted to trace the center dotted line of a star shaped pattern. Both speed and accuracy were emphasized. The total time (speed) and the length of the line drawn (accuracy) were measured and served as the learning index.

RESULTS

Data analysis

1) Analysis of the learning effect on the practice task: Eight trials (1, 3, 5, 7, 9, 11, 13, 15) on the speed index and three trials (1, 7, 15) on the accuracy index were selected with the mean scores plotted in Fig. 1, because the mean performace curves are relatively simple and smooth. The learning effect on each index was tested by ANOVA. Table 1 presents the significant effect of leaning on both the two indices.

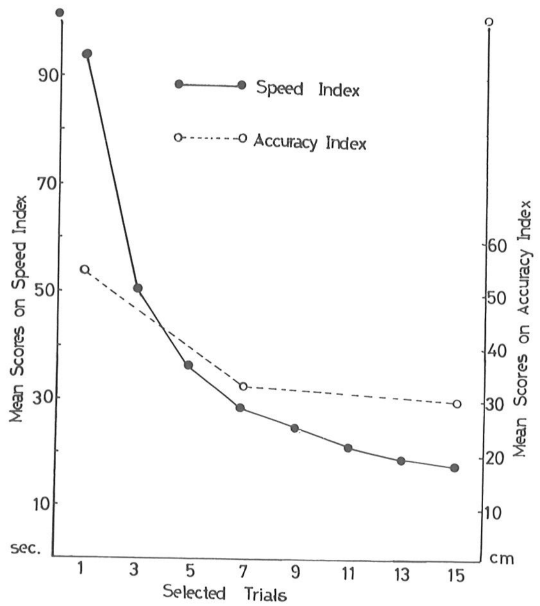

Fig. 1. Acquisition curves of performance on the speed and the accuracy index

2) Principal component analysis: For each reference test and practice task the raw scores were transformed into z-scores. Pearson

Table 1. ANOVA for learning effects

	Speed index			Accuracy index		
Source of variation	df	MS	F	df	MS	F
Between people	50	1862.72		50	159.45	
Within people	357	33691.35		102	8991.03	
Learning effect	7	33322.74	90.40[a]	2	8848.19	61.94[a]
Residual	350	3368.61		100	142.84	
Total	407			152		

a: $P < .001$

Table 2. Correlation matrix

Variables		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 Mirror Drawing Task (Speed)	1		75	79	52	48	47	49	42	47	07	-16	-21	-17	-05	-22	-48	-47
2 "	3			86	63	60	54	53	57	40	20	-12	-34	-31	-19	-37	-49	-52
3 "	5				79	69	65	65	60	40	22	-19	-38	-17	-15	-37	-41	-47
4 "	7					76	79	75	72	20	17	-30	-29	-18	-25	-37	-26	-29
5 "	9						84	85	84	19	04	-24	-32	-19	-09	-33	-28	-34
6 "	11							82	82	10	-07	-28	-35	-18	-17	-38	-36	-39
7 "	13								84	17	-12	-26	-27	-16	-04	-27	-30	-30
8 "	15									18	08	-26	-21	-16	-04	-35	-26	-31
9 Mirror Drawing Task (Accuracy)	1										27	00	-11	-26	-10	-28	-41	-36
10 "	7											29	-14	-08	-26	-11	-17	-16
11 "	15												-03	10	-10	09	11	08
12 Eye measuring test														51	59	64	55	53
13 Visual pursuit test															33	58	56	58
14 Identical number-order																46	34	32
15 Coding test																	54	55
16 Copying test																		70
17 Block-counting test																		

* Decimal points are omitted.

product-moment correlations between the reference tests and the selected practice task trials were obtained. The inter-correlations among the 17 variables are presented in Table 2. The matrix was analyzed with principal component method. The criterion to determine the number of principal components to retain was an eigenvalue greater than 1.0 (Kaiser, 1960). Four components meeting the criteria extracted (Table 3), and also component scores for each Ss were computed (Table 4).

Table 3. Principal component matrix.

Test		Components *			
		1	2	3	4
1. MDT Speed	1	708	090	447	-269
2. 〃	3	815	017	330	-053
3. 〃	5	861	159	310	033
4. 〃	7	814	316	-021	236
5. 〃	9	817	382	-118	152
6. 〃	11	816	347	-256	115
7. 〃	13	783	450	-164	046
8. 〃	15	774	412	-112	148
9. MDT Accuracy	1	417	-254	559	-262
10. 〃	7	161	-337	517	542
11. 〃	15	-253	-316	336	527
12. Eye measuring		-559	538	334	-190
13. Visual Pursuit		-459	575	258	249
14. Identical number-order		-326	565	228	-425
15. Coding		-607	480	303	-007
16. Copying		--635	498	-019	279
17. Block-counting		-658	460	-009	242
Eigenvalue		7.223	2.686	1.542	1.251
Accum. %		42.489	58.293	67.369	74.728

* Decimal points are omitted.

Component 1 loaded highly on speed index variables (No. 1–8) and also correlated to both the first accuracy index (No. 9) and all printed test variables (No. 12–17), which are time limited tests. This componet appears to be most related to speed.

Component 2 loaded primarily on all the printed tests. It seems to be justifed in characterizing this component as a mental abilities component involving visual and spatial perception.

This component also correlated to the speed index variables (No. 1, 2, 3) of early practice positively (negative relation), and to accuracy index (No. 10, 11) negatively (positive relation).

Component 3 loaded on all accuracy index variables (No. 9, 10, 11) at relatively high level, and also related to the speed index variables (No. 1, 2, 3) of early practice and two of the printed test variables (No. 12, 15). This component seems to have accuracy as its main characteristic.

Component 4 loaded on all the variables except No. 10, 11, 12. Judging from the loadings component 4 should be investigated with further experimental study.

The relationship between the two learning indices during practice.

Fig. 2 and 3 present each component pattern in relation to the learning processes. The results illustrated that in the early stages, both

Table 4. Individual component scores for each subject.

Ss	Components 1	2	3
1	.52	-.15	-.36
2	-.86	.43	.45
3	-.92	.58	.23
4	.48	-.51	-.41
5	.08	-.01	-.24
6	.18	-.24	-.00
7	.02	-.78	-.43
8	-.71	.05	.15
9	-.03	-.02	-.40
10	1.09	.21	-.49
11	--.01	.02	-.11
12	.75	.11	-.37
13	.15	-.53	.68
14	-.32	.12	-.51
15	.02	.53	-.07
16	-.57	.39	-.07
17	-.54	.04	-.04
18	1.15	-.11	.08
19	-.23	.01	.24
20	-.06	.44	-.16
21	-.03	-.44	.25
22	1.27	-.09	.06
23	-.09	-.46	.09
24	.08	-.21	.07
25	1.31	1.10	-.18
26	-.87	-.10	.24
27	-.18	-.77	.03
28	-.24	.48	.14
29	-.69	.38	-.29
30	1.40	.47	.79
31	.05	-.16	-.05
32	-1.07	.12	.13
33	-.20	.09	-.27
34	.10	.55	.14
35	-.51	-.68	-.20
36	-.65	-.13	.09
37	-.46	.22	-.27
38	.39	.20	.36
39	-.19	.30	-.30
40	-.40	.03	.29
41	--.67	-.37	-.12
42	-.66	-.15	.21
43	1.43	-.75	.47
44	.30	-.42	-.38
45	.84	.08	.44
46	.87	.41	-.03
47	-.45	-.09	.20
48	.33	-.21	-.05
49	.13	.14	-.37
50	-.93	.40	.11
51	-.41	-.53	.19

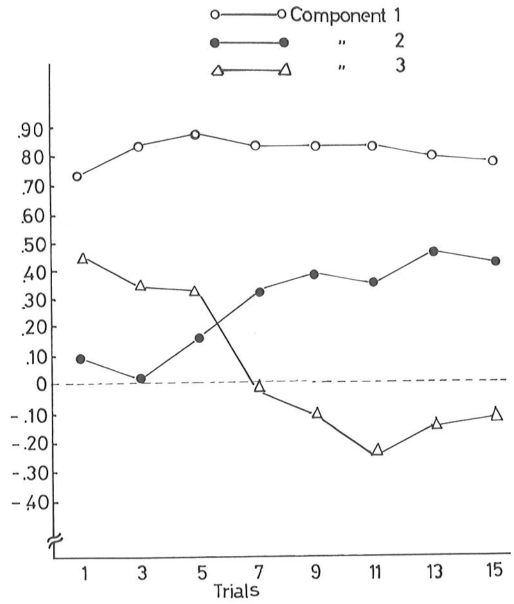

Fig. 2 Component pattern on "speed" leaning index

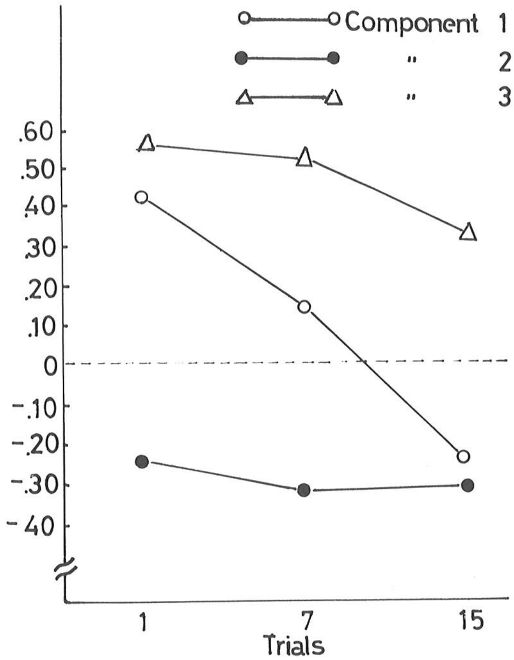

Fig. 3. Component pattern on "Accuracy" learning index

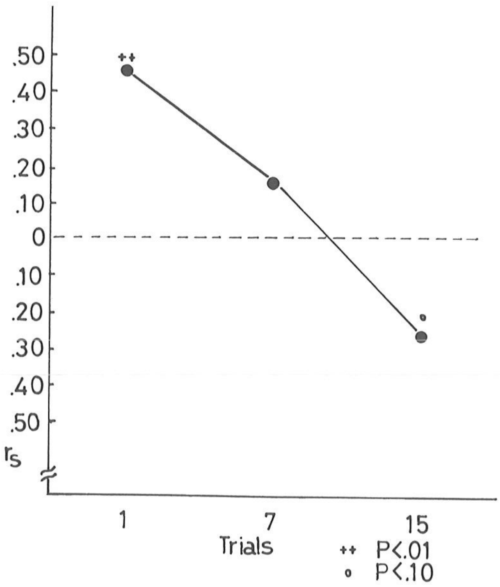

Fig. 4. The correlations between "Speed" and "Accuracy" index.

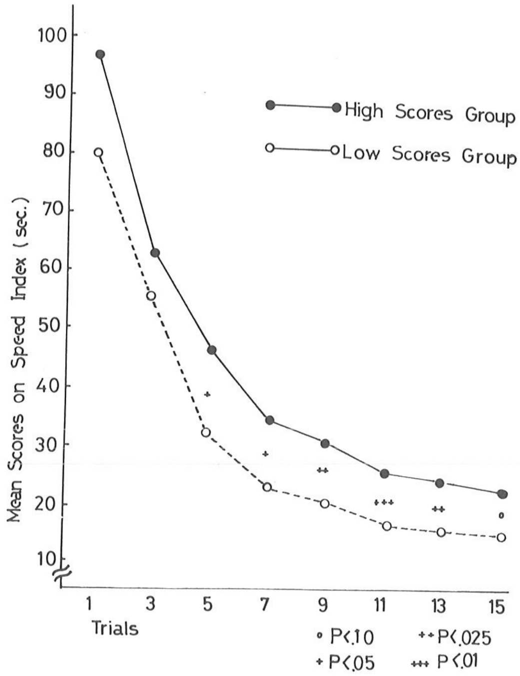

Fig. 5. Acquisition curves of High and Low score groups on the speed learning process.

components 1 and 3 correlated positively with the speed and accuracy indices. Component 3 decreased on loadings for succeeding stages of the speed index (Fig. 2) and component 1 decreased to the negative level for succeeding stages of the accuracy index (Fig. 3). These patterns would seem to suggest that there is a positive relation between the two indices in the early stages of practice but, by the late stages, the relation changes to a negative level. The same tendency is also illustrated in Fig. 4 which presents the correlation coefficients between the two indices at the three stages. With regard to the relation of non-motor abilities to the speed and accuracy processes, the pattern of component 2 indicated that the non-motor component had a negative effect on the "speed" performance during the late stage of practice (Fig. 4). On the other hand, the non-motor component was related to the "accuracy" performances at all stages (Fig. 5).

Types of individual differences on the non-motor component

Both "high (n=10)" and "low (n=10)" scores groups were extracted from the total Ss on the basis of their scores from component 2 (Table 4). The mean scores achieved by the two groups in the successive stages of the two indices are shown respectively in Fig. 5 and 6.

It can be seen that Low Score Group tended to be superior to High Score Group on "speed"

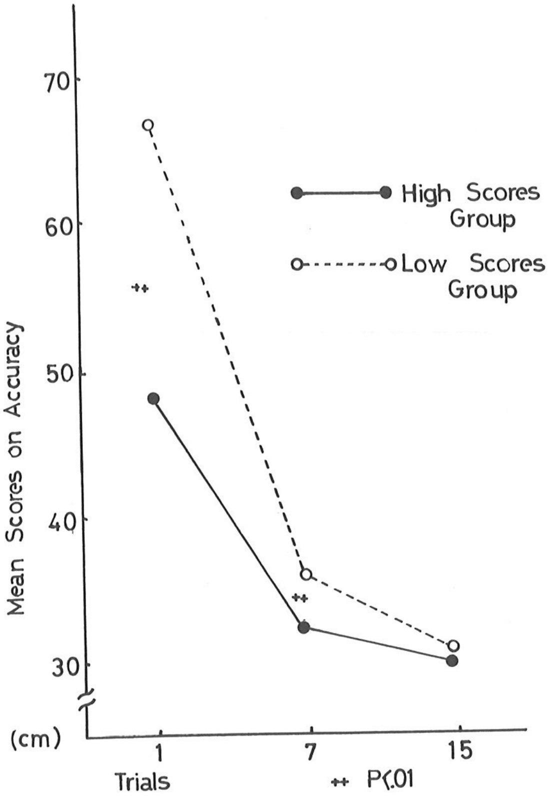

Fig. 6. Acquisition curves of High and Low score groups on the accuracy learning process

performance, while the High Score Group tended to be better on "accuracy" performance. The Mann-Whitney U test was used to test the significance of the differences between the two groups at each practice stage.

DISCUSSION

It can be seen in Fig. 2 and 3 that the component structures of the two learning indicants in early stages were relatively similar. However, for the last stage the structures changed appreciably. Moreover, the correlation between the two learning indices at each stage (Fig. 4) indicated that the relationship might change with practice. These results would seem to suggest that perceptual-motor learning could be characterized by multiple processes, not by a single process, and also the relations among the learning processes could be changed with practice. Especially in the early learning stages there could be a certain generality among the learning processes. Considering these results, it would seem to be indicated that the role of abilities required could be different in each different learning process (e.g., speed, accuracy) as well as at different stages of practice (e.g., early, late). According to Fleishman (1954), non-motor factors play a role in the early stages of skill learning. From a more specific view point, the role of non-motor factors could be different in various learning processes of a task. In the present study, the role of the non-motor component (component 2) plays a positive role in each stage of the "accuracy" learning process, while it plays a negative role during the later stages of the "speed" learning process. From another view point, these results suggest that the individual differences on the non-motor component could effect the performances of the two learning processes in different ways. Fig. 5 demonstrates that the High Score Group on component 2 was significantly superior to the Low Score Group in the early and middle stage of the "accuracy" learning process. On the other hand, the Low Score Group tended to be significantly superior to the High Score Group in the latter half of the "speed" learning process. This phenomenon might be described as follows: The "accuracy" learning process requires more exteroceptive cues. On the contrary, the same cues play a negative role on the late stages of "speed" learning. Therefore, the High Score Group who would be more sensitive to exteroceptive cues than the Low Score Group performed better on the "accuracy" learning process but worse in the latter half of the "speed" learning process. Thus, component scores for each subject would appear to be a more effective predictor of performance level than row test scores. This assumption must await further investigation.

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