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Author	Namiki, Hiroshi Hayashi, Junko Shibata, Takeshi
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Specificity-Generality of Aptitude Information in the Aptitude-Treatment Interaction: An Experimental Evidence

Hiroshi Namiki,[1)] *Junko Hayashi*[2)]
and Takeshi Shibata[3)]

The present experiment was designed to complete a series of ATI research on establishing a method for determining the optimal instructional treatment when two aptitude informations and multiple treatments are combined. Under four types of instructional treatments, Text-Numerical, Text-Graphical, Program-Numerical, and Program-Graphical, junior high school pupils were taught a learning task of understanding and applying a formula to summate arithmetic progression. Six aptitudes were measured including specific and general ones. By revising the pretest and the measure of payoff used in the preceding experiment, more decisive conclusions were drawn that specific aptitude informations were more advantageous in yielding significant ATIs than general ones, quite contrary to the result of the similar preceding experiment. Possible causes of this discrepancy were discussed in relation to the subtlety ATI has.

Individuals differ in their best suited environment for learning. A recurring problem of the institution, therefore, resides in designing and providing an educational environment that is flexible and adaptive enough to deal with individual differences manifested along diverse dimensions. In designing such an adaptive educational program, however, the process underlying the interchange between a

1) Associate Professor of educational psychology in the Faculty of Letters, Keio University.
2) Master of Education, Graduate School of Keio University.
3) Research staff of the Center for Education in Adachi-ku, the Tokyo Metropolis.

learner and an environment needs to be explicated.

The most pertinent and useful conceptualization of this underlying process seems to the authors to be the aptitude-treatment interaction, or in abbreviation, ATI, advocated by Cronbach (1957) some twenty years ago. ATI research has a profound significance both theoretically and practically. Its theoretical importance lies in the generality it has in explaining human behavior including teaching-learning process (Hunt and Sullivan, 1974; Namiki, 1978). The practical aspect of its importance is that instructional methods optimally adaptive to individual diversity could possibly be designed through the inspection of an interactional pattern among learner's aptitude, characteristics of instructional treatments, and the structure of a learning task.

While the experimental identification of ATI effect is acknowledged as an important task in the science of instruction, many researches have not necessarily been successful hitherto in finding significant interactions. In addition, no agreement has been reached among researchers interested in ATI about the condition under which a significant interaction occurs. One of the problems at issue is whether significant ATIs are obtained from general aptitude informations or specific ones. The senior author has tried to analyse this problem from somewhat theoretical point of view elsewhere (Namiki, 1977a), and arrived at the conclusion that significant ATIs should be obtained from general aptitude informations by designing alternative instructional treatments appropriately.

A series of ATI experiments have been performed by the authors to establish a method for determining optimal instructional treatments in ATI when two aptitude informations are taken into account simultaneously under multiple treatments. (Hayashi and Namiki, 1975; Namiki and Hayashi, 1976; Namiki, 1977b; Namiki, Hayashi, and Kazama 1977; Namiki, Hayashi, and Shibata, 1977; Namiki and Hayashi 1977). The present research was designed to complete the series of experiments by revising the pretest and the measure of payoff used in the last experiment (Namiki and Hayashi, 1976; 1977), and also by refining the method of multiple regression analysis. Thus, the findings obtained from the present experiment are expected to contribute to drawing a more substantial and decisive conclusion concerning the ATI effect of this sort as well as the specificity-generality problem of aptitude information.

Method

The method of the present experiment is almost the same as that of the last experiment except for minor change of several instruments. Detailed description of the method can be known by reference to the last experiment (Namiki and Hayashi, 1977).

Learning task

The learning task of the present experiment is to understand and apply formula for the summation of an arithmetic progression.

Treatment factors

Factors of instructional treatments are format of material (Text-Program), and type of representation (Numerical-Graphical). The former factor compares between traditional textbook format and linear program format; the latter between a numerical representation which uses mainly numerical expressions and a graphical representation where figures are used instead of numerical expressions. By combining these two factors, four instructional treatment conditions were arranged as follows: (1) Text and Numerical (T-Num), (2) Text and Graphical (T-Gra), (3) Program and Numerical (P-Num), and Program and Graphical (P-Gra).

Aptitude information

Aptitude informations were obtained by the following six measures which varied in the degree of generality, and in the aspects of mental functioning. As for the intellectual aspect, general intelligence (ISS) was measured as a general aptitude, pretest score as specific one, and grade point of mathematics as an aptitude with moderate generality. The pretest used in the last experiment showed a ceiling effect, and thus was of little use as an aptitude information. The pretest of the present experiment was revised so as to have a proper difficulty level and to cover the basic and essential skills required to master the learning task. As for the personality aspect GAT score was used as a general aptitude, State-Anxiety score (A-State) as specific one, and Learning Anxiety score of GAT as an aptitude with high generality but factorially simpler structure.

Measure of payoff

The dependent variable is posttest score as a measure of payoff, and consists of items which tap the conceptual grasp of the formula, and the application of the formula to numerical examples. Thus the posttest might tap the learning outcome more multidimensionally than that used in the last experiment.

Subjects

Subjects were second grade pupils of six classes in a junior high school located in an urban area of the Tokyo Metropolis. Each class consisted of about forty pupils, and halves of each class were assigned to each instructional treatment. Three halves from three classes therefore composed one instructional treatment group. Resulting sample size of each group was 56, and the sum total was 224, because school records of some pupils were deficient. In the result, four groups were completely matched with regard to six aptitude measures.

Procedure

In the session 1, GAT, pretest, and A-State were administered in succession. A-State was measured afterward on the anxiety state during the pretest. In the session 2 a week later, subjects were given learning materials in booklet form individually, and the learning period was 30 minutes. Immediately after the learning period, posttest was administered with a time limit of 10 minutes. No notice was given in advance to students of the test to be administered after the learning period, while in the last experiment it was given to arouse learning motivation.

Results and Discussion

Significance tests of ATI effect and main effect

Data were analysed by multiple regression analysis using step-down method (Overall and Spiegel, 1969). The pertinence of this method to the analysis of ATI data has been pointed out by the authors elsewhere (Namiki and Hayashi, 1977). Two instructional treatment factors were treated as binary vectors, and other aptitude informations as continuous vectors, both of which were included in the multiple regression equation. Two aptitude informations were treated in combination simultaneously; the one was intellectual aspect, and the other was emotional aspect. Among the possible interaction terms obtained by combining two instructional factors and two aptitudes, only those terms that define ATI were included in the multiple regression equation.

In applying multiple regression analysis to the data obtained from such an experiment as the present one, namely, when variables in the multiple regression equation—main effect terms and many interaction terms from first order to higher order—are not mutually independent, the estimation of relative contribution of each variable to multiple correlation is critically influenced by the ordering of variables in the multiple regression equation. In the present experiment, therefore, the uppermost priority in the ordering of variables was given to higher-order ATI terms since they were of primary concern to the authors. Consequently, main effect terms were the last to be included in the equation, and tend to be unduly under-estimated when full models were composed of too many variables. The number of priority in the Table 1 and 2 means the priority of ordering appointed to each term in the multiple regression equation in advance of calculation using stepdown method. The ordering of variables within the same priority ranks was decided by the relative magnitude of contribution of each term in the particular priority rank.

The result of multiple regression analysis obtained by combining two general aptitude, ISS and GAT, together with two instructional treatment factors, is shown in Table 1. As an ATI effect, only T-P ×ISS×GAT is near to significance level. Other ATIs of higher-order and lower-order do not reach significance level. On the other hand, the main effect of ISS is markedly significant.

The result of the same analysis attained by the combination of two specific aptitude, pretest score and A-State, is shown in Table 2. In this case, three ATIs have reached significance level: T-P×pretest ×A-State, T-P×pretest, and T-P×A-State. Mention will be made of these significant ATIs in the following section.

As regards main effects, pretest score is significant. In the learning situation such as the present experiment, the pretest score as well as ISS shows markedly intense main effects, in comparison with interactions, though these factors are not given priority of ordering in the multiple regression analysis. It seems that the relatively short learning period (30 minutes) has relevance to these results. That is, regardless of the instructional treatments, subjects with high general intelligence or prior basic skills stand in an advantageous position in mastering such a learning task as is self-contained and quite unfamiliar in short period of time.

Mean payoffs of four instructional treatment groups were shown in Table 3. The average payoffs of Text format is slightly higher

Table 1. Summary table of multiple regression analysis

Factors: T-P(A), Num-Gra(B), ISS(C_1), GAT(D_1)

Step number	Variable entered	Priority	Number of variables included	Multiple R	R^2	Increase in R^2	F_{ratio}	df	P
1	A C_1 D_1	1	1	.1192	.0412	.0142	3.2016	1/222	$.05<P<.10$
2	A B C_1 D_1	1	2	.1369	.0187	.0045	1.0205	1/221	*ns*
3	A B C_1	1	3	.1513	.0229	.0041	.9337	1/220	*ns*
4	A B D_1	1	4	.1520	.0231	.0002	.0497	1/219	*ns*
5	B C_1 D_1	1	5	.1520	.0231	.0000	.0000	1/218	*ns*
6	A C_1	2	6	.1849	.0342	.0111	2.4838	1/217	$.10<P<.25$
7	A D_1	2	7	.2105	.0443	.0101	2.2896	1/216	$.10<P<.25$
8	B C_1	2	8	.2256	.0509	.0066	1.4949	1/215	$.10<P<.25$
9	B D_1	2	9	.2272	.0516	.0007	.1626	1/214	*ns*
10	C_1	3	10	.6250	.3907	.3390	118.5089	1/213	$P<.001$
11	D_1	3	11	.6286	.3952	.0045	1.5820	1/212	$.10<P<.25$
12	A	3	12	.6290	.3956	.0004	.1563	1/211	*ns*
13	B	3	13	.6290	.3957	.0001	.0273	1/210	*ns*

Table 2. Summary table of multiple regression analysis

Factors: T-P(A), Num-Gra(B), Pretest(C_2), A-State(D_2)

Step number	Variable entered	Priority	Number of variables included	Multiple R	R^2	Increase in R^2	F_{ratio}	df	P
1	A C_2 D_2	1	1	.1454	.0211	.0211	4.7937	1/222	$.01<P<.05$
2	A B C_2	1	2	.1535	.0236	.0024	.5463	1/221	*ns*
3	A B C_2 D_2	1	3	.1581	.0250	.0014	.3228	1/220	*ns*
4	B C_2 D_2	1	4	.1590	.0253	.0003	.0685	1/219	*ns*
5	A B D_2	1	5	.1593	.0254	.0001	.0213	1/218	*ns*
6	A C_2	2	6	.2788	.0777	.0523	12.3161	1/217	$P<.01$
7	A D_2	2	7	.3151	.0993	.0215	5.1667	1/216	$.01<P<.05$
8	B C_2	2	8	.3185	.1015	.0022	.5225	1/215	*ns*
9	B D_2	2	9	.3192	.1019	.0004	.0978	1/214	*ns*
10	C_2	3	10	.6933	.4806	.3788	155.3421	1/213	$P<.001$
11	D_2	3	11	.6954	.4835	.0029	1.1814	1/212	*ns*
12	B	3	12	.6955	.4837	.0002	.0652	1/211	*ns*
13	A	3	13	.6956	.4838	.0001	.0487	1/210	*ns*

than that of program format, and this tendency is in line with the result obtained from the last experiment, though the difference falls short of the significance level (cf. Table 1 and 2).

Generality-specificity problem

So far as the results of the present experiment are concerned, aptitude informations with high specificity have an advantage over those with high generality in yielding significant ATIs. These results are quite contrary to those of the preceding experiment (Namiki and Hayashi, 1977), where significant ATIs were obtained from general aptitudes either by combining two of them or by using singly. Several interpretation might be possible concerning the discrepancy between these two results. First, drastic revision of pretest and minor change of posttest could be responsible for this discrepancy. In the preceding experiment, the pretest were composed of items which required Ss to complete a number series, and were the sort usually found in intelligence test battery. The pretest score showed, however, a ceiling effect and was almost of no use for an aptitude information. Accordingly, the pretest has been revised so as to cover the basic skills to learn the task, and it is therefore more specific than that used in the last experiment. As for the measure of payoff, additional items to tap the conceptual grasp of the learning task could have changed the domain and dimension measured by them.

Second, in the last experiment subjects were informed beforehand of the posttest to be administered in order to arouse motivation. In the present experiment, however, they were not, partly because several cases of cheating during the test were detected in the last experiment.

As Cronbach and Snow (1969) put it, "Research on ATI would have to be subtle", the subtlety intrinsic to ATI must be subject to a slight difference of experimental conditions. This subtlety of ATI must be responsible also for the discrepancy of optimal solution, or placement chart, between the two experiments as will be mentioned in the next section.

Determination of optimal instructional treatment with two aptitude informations and four treatments

Following the solusion method developed by the authors, regions of optimal instructional treatments, or placement chart, were obtained so as to divide the plane defined by the two aptitude dimensions. This method has been developed with the purpose of increasing the generality of ATI methodology, and proved to be valid by a series of researches. According to this method, optimal instructional treatments are determined as a orthogonal projection of the polyhedron formed by optimal instructional treatments onto the plane of two

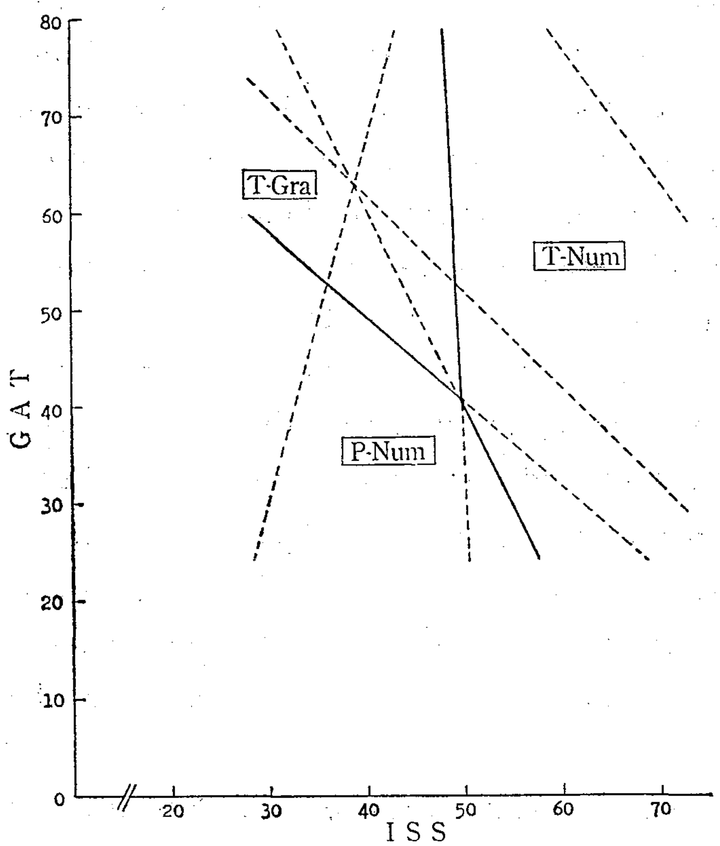

Fig. 1. Regions of optimal treatment when ISS and GAT are used as aptitude. Dotted lines are also orthogonal projections of intersections, but not effective for optimization.

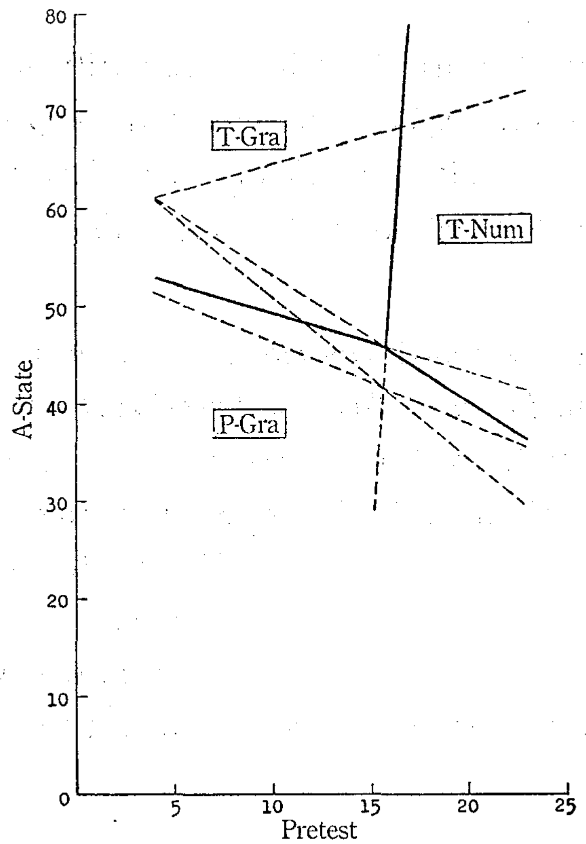

Fig. 2. Regions of optimal treatment when Pretest and A-State are used as aptitude. Dotted lines are also orthogonal projections of intersections, but not effective for optimization.

aptitude dimensions (Namiki, 1977b; Namiki and Hayashi, 1977).

The optimal treatment with ISS and GAT is shown in Fig. 1, and with pretest and A-State in Fig. 2, respectively. The placement chart of Fig. 1, however, has not sufficient reliability because the higher order interaction term yielded by combining two aptitude informations and treatment factors is short of significance level as shown in Table 1. The pattern of optimal instructional treatment shown in Fig. 2 has relatively high reliability since the multiple regression analysis yielded the significant interaction of T-P× pretest×A-State. Strictly speaking, the other instructional treatment factor, Num-Gra, is not included in this significant interaction term, and thus the reliability of the pattern shown in Fig. 2 is only partly substantiated.

These placement charts bear little similarity in pattern to those obtained from the last experiment though the experimental settings are quite similar (cf. Fig. 2 in Namiki and Hayashi, 1977). In this fact is found another reflection of subtlety the ATI study has intrinsically.

Determination of optimal instructional treatment with single aptitude information and four instructional treatments

Four regression lines of payoff, corresponding to each instructional treatment, onto each aptitude dimension were calculated. Disordinal interactions which were reliable and effective for optimization could be obtained from several aptitude informations. In testing the significance of ATI with single aptitude, reduced models were used which contained one aptitude variable and two instructional treatment fac-

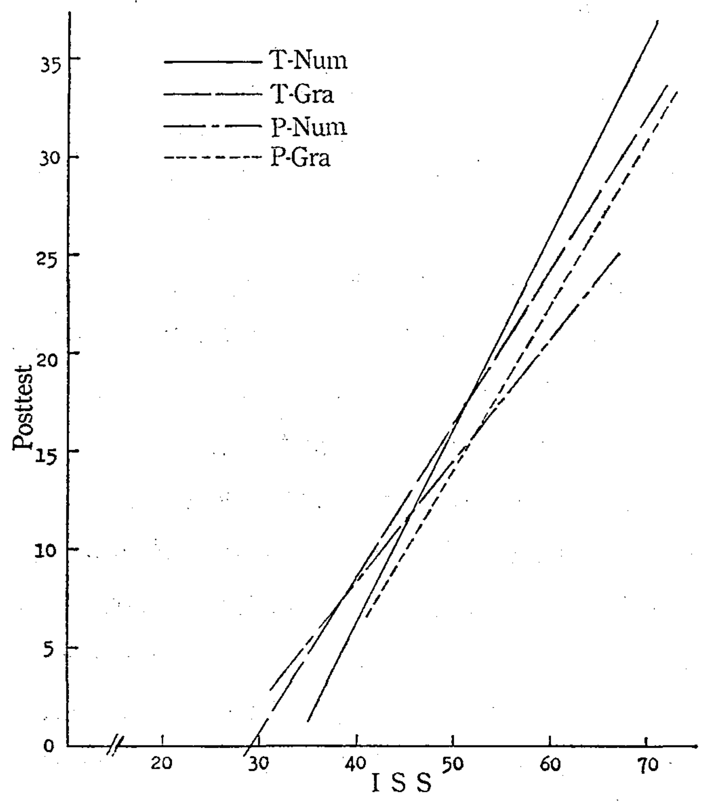

Fig. 3. Regression-lines of four instructional treatments when ISS is used as aptitude.

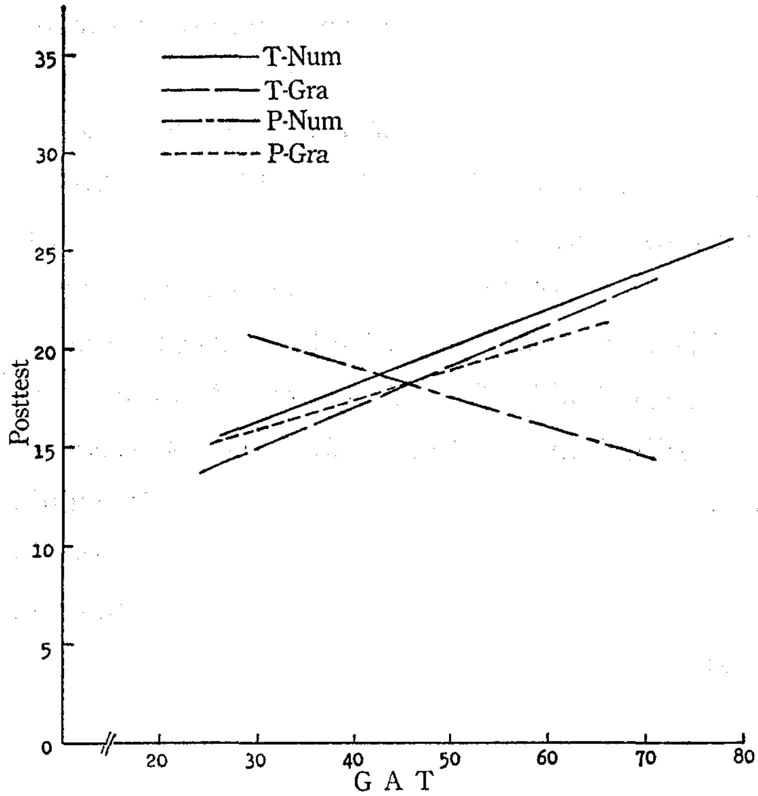

Fig. 4. Regression-lines of four instructional treatments when GAT is used as aptutude.

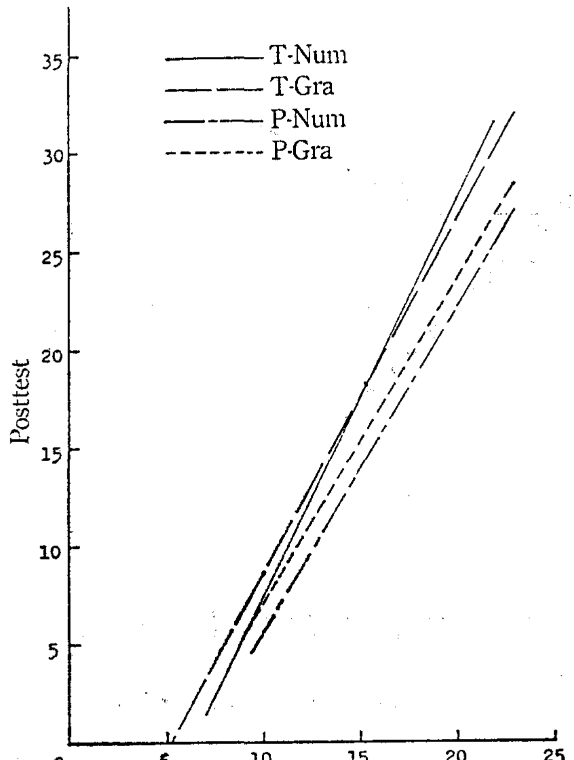

Fig. 5. Regression-lines of four instructional treatments when Pretest is used as aptitude.

tors, besides the multiple regression analysis with two aptitude informations such as shown in Table 1 and 2.

The ATI with ISS is shown in Fig. 3, and this is not significant. Fig. 4 is the ATI with GAT, and seemingly there exists a marked disordinal interaction valid for optimization, but it falls short of the significance level. The ATI with pretest score is shown in Fig. 5, and the significance of this interaction is partially substantiated by multiple regression analysis (cf. Table 2). As regards A-State score, a reliable and efficient disordinal interaction is observed as shown in Fig. 6. In this case, placement to three instructional treatments should be done at the crossover point of 45 and 57 on the abscissa of A-State. The grade point of mathematics and Learning Anxiety of GAT did not yield any significant ATI.

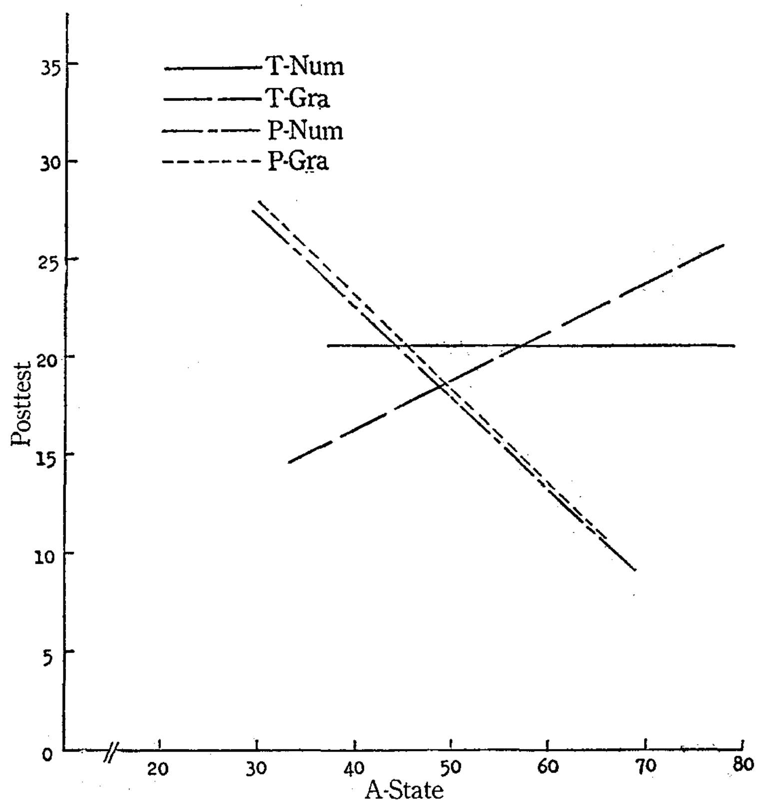

Fig. 6. Regression-lines of four instructional treatments when A-State is used as aptitude.

Improvement of payoffs yielded by optimization using two aptitude informations and single one

In Table 3 are shown mean payoffs of four instructional treatments and those of optimized treatments. The means of optimized instruction were calculated by picking up every subject who happened

Table 3. Means and Standard deviations of payoff in each instructional treatment group without and with optimization.

				T-Num	T-Gra	P-Num	P-Gra	Total Mean
(not optimized)			*M*	20.54	18.86	17.86	18.34	
			SD	10.84	10.62	9.58	9.94	
			N	56	56	56	56	
Aptitude used for optimization	Two aptitudes	ISS & GAT	*M*	23.81	13.60	11.17	—	21.46
			SD	9.60	7.81	4.74		10.17
			N	43	5	6		54
		Pretest & A-State	*M*	25.97	11.14	—	18.00	20.75
			SD	8.58	6.42		11.54	10.76
			N	30	14		8	52
	Single aptitude	ISS	*M*	24.86	13.00	6.50	—	19.98
			SD	9.54	8.36	2.50		10.89
			N	37	22	2		61
		GAT	*M*	21.59	—	20.30	—	21.19
			SD	10.83		8.14		10.09
			N	44		20		64
		Pretest	*M*	25.11	9.62	—	—	19.40
			SD	9.09	5.77			10.97
			N	36	21			57
		A-State	*M*	22.19	22.30	—	23.21	22.47
			SD	10.50	12.45		11.03	11.03
			N	31	10		14	55

* The dash in the cell indicates that the corresponding instructional treatment is not used for optimization.

to be treated under optimal condition for him. For example, when ISS and GAT are used as aptitudes simultaneously, 43 subjects chanced to be treated under their optimal treatment of T-Num, 5 under T-Gra, and 6 under P-Num, and none under P-Gra (P-Gra condition did not appear as an optimal treatment at all). Totally 54 subjects were optimally instructed, yielding a mean payoff of 21.46.

Comparison of mean payoffs of not optimized four treatments with those of optimized treatments indicates that the improvement of payoff by optimization evidently occurs. The largest improvement, however, was yielded by optimization with single aptitude (22.47 with A-State), but not with two aptitudes. Namely, single aptitude information suffices for the purpose of optimization, in so far as an achievement test score is regarded as the measure of learning outcome. This result is completely in line with that of the last experiment.

Concluding remarks

In so far as the ATIs of this sort are concerned, significant ATIs are obtained from more specific aptitude informations. The discrepancy between the result of the preceding experiment and that of the present one seems to give us warning of the subtlety ATI has inherently. More stable and substantial ATIs should be identified experimentally before we can speak of practical utility of the ATI research. One of the possible research strategies is to make the duration of instructional treatment much longer, as Cronbach and Snow (1977) point out. Admittedly the learning period of the present experiment is too brief, and needs to be improved hereafter.

As for taking two aptitude informations into account simultaneously, it must await further experimentation to decide "whether it is a step toward new conceptions of aptitude or singly an interesting demonstration built on chance", as Snow puts it (1976). The authors are of opinion that using two aptitude informations simultaneously, especially intellectual and emotional ones, is to take a step further to the realization of adaptive education (Glaser, 1977). In this regard, the result thus obtained from optimization suggests that the pertinence of the measure of learning outcome needs to be reexamined from a different point of view.

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