Discriminative Reaction Test of Multiple Performance Type: A Test for Discrimination of Accident Proneness in Motor Driver

DISCRIMINATIVE REACTION TEST OF MULTIPLE PERFORMANCE TYPE: A TEST FOR DISCRIMINATION OF ACCIDENT PRONENESS IN MOTOR DRIVER*

by

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It is true that the discriminative reaction time test[1] has been so far a useful device for the discrimination of motor driver's accident proneness, but we find it necessary to contrive a test which is higher in its adequacy, in other words, higher in its efficiency ratio** than the test mentioned above.

It is the purpose of the present paper to report the results of a tentative application of the new test designed to meet the requests. This test is chiefly concerned with the aspects of coordination of perceptual-motor functions in drivers.

It was found that accident drivers and non-accident drivers could be classified by a discriminative reaction test[1]. In that test the indexes of mean reaction time ($\overline{X}$), error reaction (E) and coefficient of variation (V) were used for the classification. The latter two of indexes showed significant differences between the two groups of drivers. That is, E and V tended to become greater for the accident drivers. Moreover, $\overline{X}$ tended to reduce for the accident drivers. The tendency of increasing of E and V, and reducing of $\overline{X}$ in accident drivers seemed to suggest that the accident drivers were apt to be impatient or to lack control at a critical moment or when prompt judgement, continuous concentration and distribution of attention were required. Especially it was assumed that these tendencies would become more remarkable as the complexity of task increased.

On the basis of this assumption, with the purpose of discriminating accident drivers more distinctly from non-accident drivers than before, two new test conditions which would complicate the task situation were added to the former procedure.

(1) Condition which repuires twofold performances.
(2) Condition which repuires occasional changes of already established type of performances.

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** A detailed account about the efficiency ratio will be given later.

Concreate procedure of these conditions will be descrived later.

This new method was designed when a comprehensive survey on drivers was required by the Senpoku Railway and Bus Company(仙北鉄道株式会社)* and was tentatively used as one of the test battery of 10 tests for the company, as was mentioned in the paper by Maruyama[2]. Since the results that confirmed our assumptions were obtained, they will be reported in detail.

Method

Subject : Totally 69 Ss consisted of 4 groups.** They were the same persons that took the Speed Anticipation Test reported by Maruyama.

Apparatus : Photographs of the apparatus were presented in Fig. 1. As is known from the figures, there are 3 round windows, which were 3 kinds of stimuli, (each 3 cm in diameter) on the 75 × 70 cm black screen in horizontal direction having green light, yellow light and red light from the left-hand-side, respectively. They are 33 cm distant from each other and are on a little higher level than the eyes of the S. The presentation of green light was to be reacted with right hand, yellow light with left hand and red light with foot by letting go

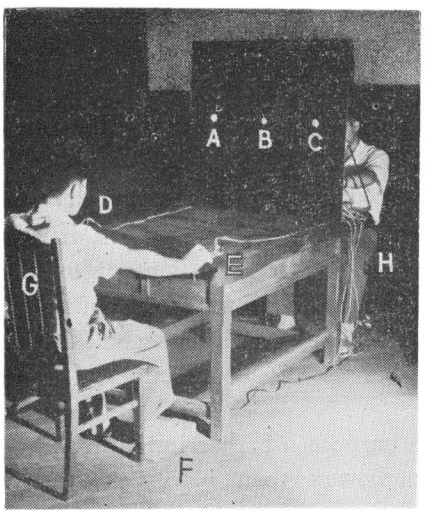

Fig. 1—1.
A: Green light B: Yellow light
C: Red light D: Left hand key
E: Right hand key F: Right foot key
G: Subject H: Experimenter

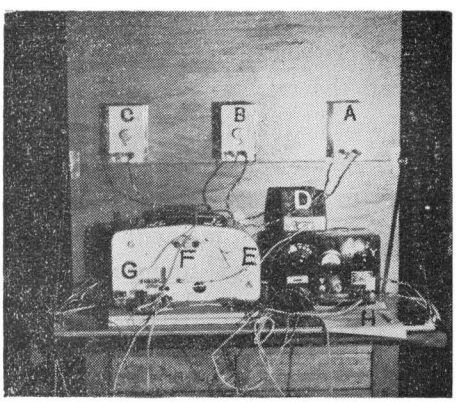

Fig. 1—2. Backside of the screen.
A: Green light box B: Yellow light box
C: Red light box D: Buzzer
E: Dial plate
F: Lamps for detecting error
G: Keys for presenting stimuli
H: Recording paper

* The writers heartily thank all the staff members of the Senpoku Railway and Bus Company (仙北鉄道株式会社) in helping our research.

** On the detailed account with respect to the classification of Ss, see the paper by Maruyama[2].

one's hold of the electric key, respectively. Behind the screen was set a chronoscope, by which $\overline{X}$ and E were measured, with a compact synchronous motor and buzzer. The buzzer was a new device used for the first time. S was seated facing the screen, 1 m distant from it.

Procedure : The test consisted of two parts.

Part I (The former method)

Subject was required to keep pushing down 3 electric keys at the signal of "ready" on the part of Experimenter and to be waiting for the next directions of Experimenter. After it was ascertained that the keys were all pushed down through pilot lamps attached to the chronoscope, some practice performances were carried out as below. Presenting the green light first, Experimenter gave instruction to let go one's hold of the right hand key, then, presenting yellow light, to loose one's hold of the left hand key and presenting red light lastly, to set free the right foot key. For each of three lights, four times of practice performances were exercised.

Subject should take every possible care to react by only one of the three keys and not to loose his hold of more than two keys at a time. If he did so, it would be counted as an error reaction. Then the following instruction was given lastly: "Will you please react correctly and as fast as possible?" Stimulus lights were presented 16 times with different frequency for each color in random order as shown in Table 1.

Table 1. Order of presentation of 16 stimuli in Part I.
(G: Green light, Y: Yellow light, R: Red light)

Order of presentation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Stimulus light	G	G	Y	G	R	G	G	Y	G	Y	G	G	R	G	Y	G

Part II (The new method)

The following instructions were added to those of the Part I.

(1) Not to let off the key when a buzzer goes simultaneously with light (the 80 phon buzzer was actually sounded before the test to make sure).

(2) To count how many times each stimulus light was presented during the reacting performances and to report them at the end of the test. This task may be thought as an obstructive one to the reaction performance.

Thus, in part II, the performances of occasional restraints of reaction and of counting and memorizing the times of presentations of each stimulus were required, in addition to the only one kind of performance of reaction in Part I. Under such situation, it was assumed that without relevant judgement and without concentration and distribution of attention to the threefold tasks, the performances would deteriorate. The order of presentation of stimulus lights was shown in Table 2. In Part II also, each S reacted 16 times. The position where a buzzer was sounded was indicated by a circle sign.

Table 2. Order of presentation of 16 stimulus lights in Part II.

Order of presentation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Stimulus light	G	Y	Ⓨ	Ⓡ	Y	G	R	R	Y	Y	Ⓖ	R	Ⓨ	R	Y	Y

Results

Part I

(a) *Mean reaction time* ($\overline{X}$) ..... In principle $\overline{X}$ was calculated by averaging the total time of 16 reaction tasks. Reaction time where error reaction occurred was omitted from the calculation. Distribution curves were presented in Fig. 2 and $\overline{X}$ for each of the four groups in Table 3. A significant difference was found between non-accident group and accident group ($t_0 = 2.44$, $df = 39$, $p < .05$). It may be said that the accident drivers reacted (set free the key) faster than the non-accident.

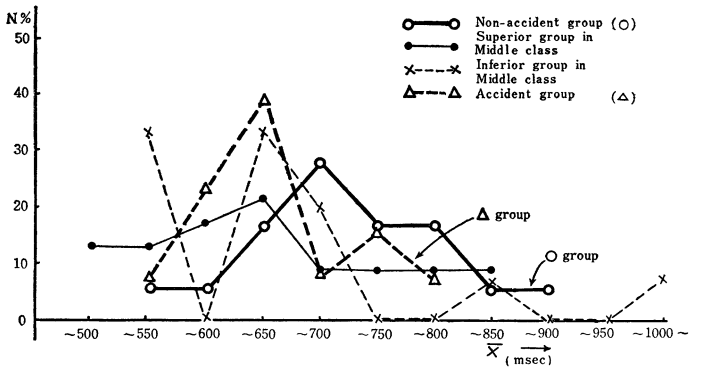

Fig. 2. Distribution curve of $\overline{X}$.

Table 3

Group \ Index	$\overline{X}$(msec)	$\frac{SD}{\overline{X}} \times 100(\%)$
Non-accident group	701.4	13.4
Superior group in middle class	631.3	10.1
Inferior group in middle class	657.2	25.1
Accident group	623.6	16.3

Regardless of this finding, this index was not used for discrimination of each driver, because it was a problem how we should settle the criterion to discriminate between qualifying and disqualifying scores.

(b) *Error reaction* (E) ..... This is the index with which non-accident and accident groups have been most distinctly discriminated. On the basis of the past and the present data, the following criterions were settled:

errors 3 times and below ..... qualified scores
errors 4 times and over ..... disqualified scores.

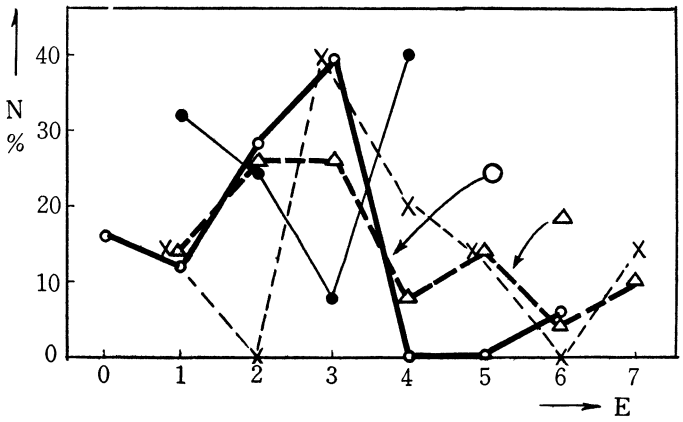

Fig. 3. Distribution curve of E.

Table 4

Group \ Index	Numbers of E(mean)	SD
Non-accident group (NAG)	times 2.2※	1.42
Superior group in middle class (SG)	2.5	1.27
Inferior group in middle class (IG)	3.8	1.72
Accident group (AG)	3.3※	1.85

※ Significant at 5% level of confidence (between Non-accident group and accident group).

Table 5

Group \ Qualification	Qujaified drivers	Disqualified drivers
NAG	17	1
SG	8	5
IG	8	7
AG	15	8

Reference to Fig. 3 and Table 4 will show that non-accident drivers tend to do less error reactions more than accident drivers ($t_0 = 2.04$, $df = 39$, $p < .05$). Result of discrimination according to the criterion was shown in Table 5. The efficiency ratio* of this index as a test was 60.9 % ($\chi^2 = 7.659$, $df = 3$, $p < .05$), and so this index is considered to be a useful test index.

(c) *Coefficient of variation* (V) ..... Fig. 4 and Table 6 show the results. Criterions for discrimination were:

20.0 % and below ..... qualified scores

20.1 % and over ..... disqualified scores

* The efficiency ratio is indicated by the following formula : efficiency ratio = (members of non-accident group in qualified category + members of accident group in disqualified category) / (total Ss in non-accident group + total Ss in accident group) × 100.

Table 6

Group \ Index	V (%)	SD
NAG	16.7	6.07
SG	16.3	4.31
IG	17.8	5.80
AG	17.1	7.68

Table 7

Group \ Qualification	Qualified drivers	Disqualified drivers
NAG	12	6
SG	10	3
IG	11	4
AG	11	2

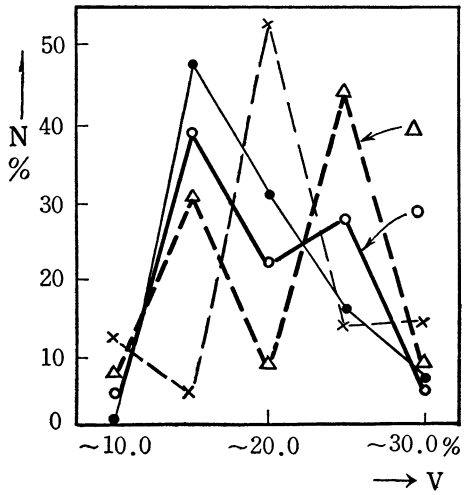

Fig. 4. Distribution curve of V.

Table 7 shows the reslts of discrimination. The efficiency ratio was 58.3% ($\chi^2 = 3.933$, not significant difference). This index cannot be an effective index by itself alone.

Part II

(a) *Mean reaction time* ($\overline{X}$).....Fig. 5 and Table 8 present the results. No significant difference was found between non-accident and accident group

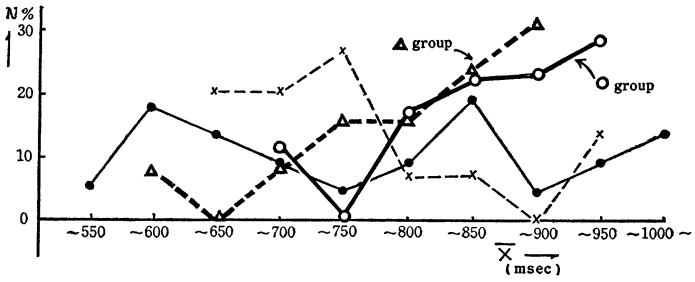

Fig. 5. Distribution curve of $\overline{X}$.

(though the difference of 115.6 msec. between the two groups was near the 5 % level of confidence).

Table 8

Index / Group	$\bar{X}$(msec)	$\frac{SD}{\bar{X}} \times 100$ (%)
NAG	878.3	34.9
SG	805.9	14.6
IG	754.4	15.3
AG	762.7	19.4

Here, in Part II also accident drivers had a tendency to react faster than the non-accident ones. But this index did not serve as a measure of discrimination, either, because of the above reason.

(b) *Error reaction* (E).....In this Part II, results were seen from three aspects; the three aspects and the criterion of each will be described below.

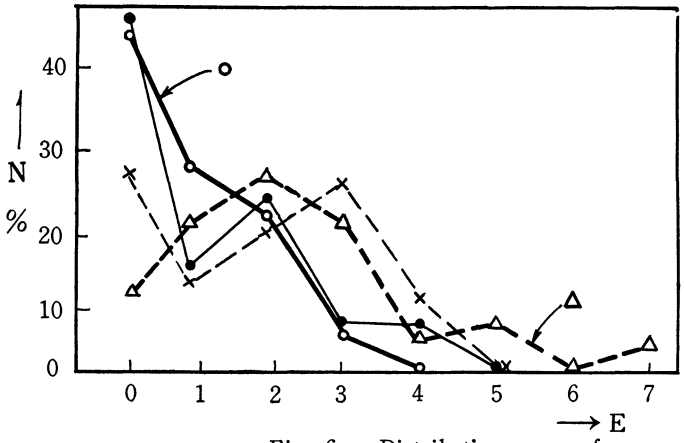

Fig. 6. Distribution curve of Aspect (1).

Aspect (1) Error reactions for 12 reactions out of 16, 4 reactions when the buzzer was sounded being left out of account. (For this index, 2 errors and below was a qualified score.)

Table 9

Index / Group	Number of E	SD
NAG	1.8 times	1.50
SG	1.7	1.58
IG	2.7	2.14
AG	4.6	1.61

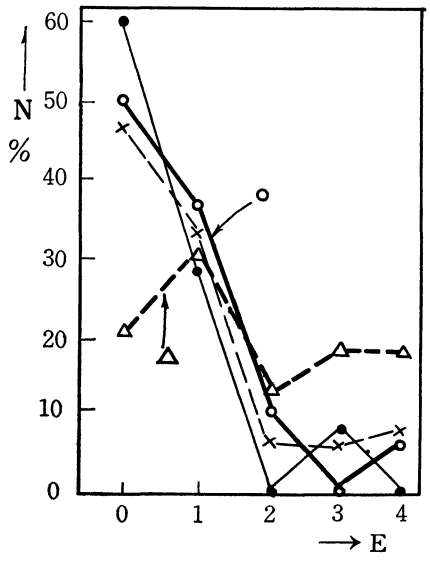

Fig. 7. Distribution curve of Aspect (2).

(2) Error reactions for 4 reactions when the buzzer went. (1 error and below was a qualified score.)

(3) Error reactions for 16 ones, in case (1) was combined with (2). (3 errors and below was a qualified score.)

Fig. 6, 7, and 8 present the distributions of error reactions for the three aspscts respectively and Table 9 shows errors for each of 4 groups in the aspect (3).

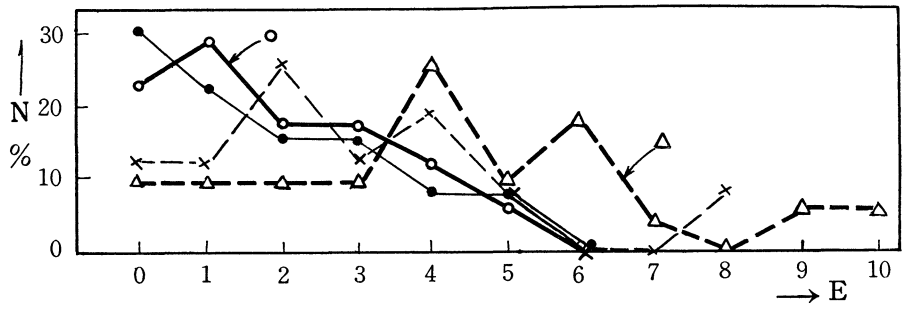

Fig. 8. Distribution curve of Aspect (3).

From there results, it follows that non-accident drivers made less error reactions than accident drivers regardless of "with" or "without" buzzer. In this connection, there was a significant difference with respect to the aspect (3) between the two groups ($t_0=5.56$, $df=39$, $p<.01$).

Results of discrimination in each of three aspects according to the criterion described above were shown in Table 10, 11 12. The efficiency ratio was rather higher than the index of E in Part I, i. e., 63.4% both in aspects (1) and (2) ($\chi^2=8.211$, $df=3$, $p<.05$; $\chi^2=8.763$, $df=3$, $p<.05$ respectively). (3), when (1) was combined with (2), resulted in the efficiency ratio of 73.1%($\chi^2=13.731$, $df=3$, $p<.01$). Even if the result of discriminatjon for coefficient of variation, which will be described

Table 10. Aspect (1).

Group \ Qualification	Qualified drivers	Disqualified drivers
NAG	17	1
SG	11	2
IG	9	6
AG	14	9

Table 11. Aspect (2).

Group \ Qualification	Qualified drivers	Disqualified drivers
NAG	15	3
SG	12	1
IG	12	3
AG	12	11

Table 12. Aspect (3).

Group \ Qualification	Qualified drivers	Disqualified drivers
NAG	15	3
SG	11	2
IG	10	5
AG	8	15

below, were combined with this, the efficiency would amount to no more than 65.8 %. The index of error reaction (both "with" and "without" buzzer) by itself, therefore, will be regarded as a good criterion of discrimination.

(c) *Coefficient of variation* (V).....Means were presented in Table 13 and the discrimination in Fig. 9. There was no difference in the mean coefficient of variation between non-accident and accident group. Result of discrimination by means of the criterion according to which qualifying score was 25.0% and below, was shown in Table 14. The efficiency ratio was 41.5 %, which is an effective criterion.

Table 13

Group \ Index	V(%)	SD
NAG	23.8	10.85
SG	22.7	9.71
IG	17.7	5.75
AG	22.8	10.10

Table 14

Group \ Qualification	Qualified drivers	Disqualified drivers
NAG	10	8
SG	10	3
IG	12	3
AG	16	7

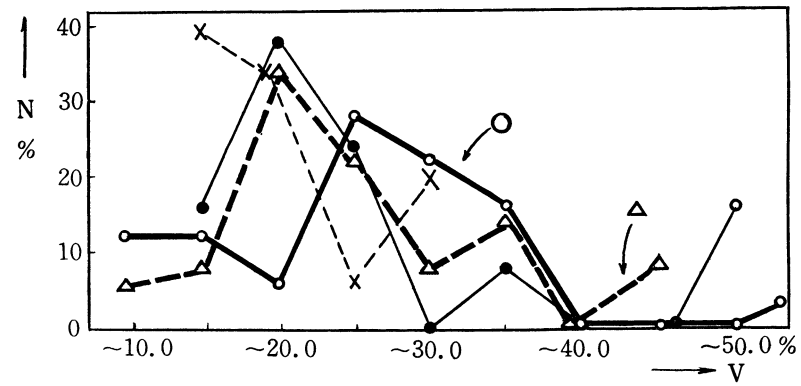

Fig. 9. Distribution curve of V.

(d) *Counting the times of presentation of each of* 3 *stimuli.*..... The data were arranged with respect to the sum of absolute value of the difference between the times presented actually by Experimenter and the times reported by Subject with each of 3 stimuli, i. e., the sum of each deviation in 3 green light tests, 8 yellow lights tests and 5 red lights tests was caliculated.

Mean absolute value of the deviation was 4.9 and there was no difference between non-accident drivers and accident drivers (Table 15). But marked individual differences were found.

Now, in order to see the effects of counting performance upon reaction performance, combining of the result of counting and of error reaction (in

Table 15

Group \ Index	Sum of absolute value of deviation (mean)	SD
NAG	5.2	2.64
SG	4.8	2.08
IG	4.5	2.32
AG	5.1	2.43

Part II) was carried out. When the value of 5 was settled as a qualifying score of counting and the result of this discrimination according to the criterion 5 was combined with that of error reaction (3) in Part II, the following relationship was found. From Table 16 it is clear that non-accident drivers belong to the category in which scores both of counting

Table 16

Group \ Category		Scores both of counting and of error reactions are qualified	Scores both of counting and of error reactions are disqualified	Scores of counting are qualified but scores of error reactions are disqualified	Scores of counting are disqualified, but scores of error reactions are qualified	Sum total
NAG	N	8	1	2	7	18
	%	44.5	5.6	11.0	38.9	100.0
SG	N	8	1	1	3	13
	%	61.5	7.7	7.7	23.1	100.0
IG	N	7	2	2	3	14
	%	50.0	14.4	14.4	21.5	100.0
AG	N	4	10	5	4	23
	%	17.4	43.5	21.7	17.4	100.0
		$\chi^2=13.404$ $df=3$ $p<.01$ ←		→ Not significant but near the 5% level of significance.		

and of error reactions were qualified; on the contrary, accident drivers to the category in which scores both of counting and of error reactions were disqualified ($\chi^2 = 13.407$, $df = 3$, $p < .01$). Further, non-accident drivers tended to keep showing better scores rather in reaction performances than in counting, without being distracted by the counting performances; while accident drivers tended to be dirturbed in reaction performance, being too much absorbed in counting (not statistically significant but near the 5 % level of significance). This index was not used as a discrimination measure, because further examination were necessary.

Discussion

In the present study, it was postulated that under complicated task situation the function of perceptual-motor coordination or the function of prompt and relevant judgement and reaction would deteriorate and, phenomenologically, scores of reaction performances would fall, and that this deterioration tendency

will be elicited much more in accident drivers than in non-accident drivers.

It is obvious from the data given above that the majority of accident drivers showed such tendencies. The accident drivers reacted faster than the non-accident ones, but they had more errors at the same time. In part II where the task was more complicated, this tendency was strengthened. Especially the results with respect to the index of the inhibition of reaction to the buzzer will offer us many suggestions as to the following: The deterioration of scores in accident drivers may have its roots either in the inferiority of coordinative functions of cognition and motor reaction or in the lack of control functions, in the fretfulness in them. Or it may be that as Drake[3] hypothesized drivers who are prone to accidents are those individuals whose level of muscular(or motor) reaction is above their level of perception. Moreover, according to the results obtained from the combination of scores of counting and error reaction, there were tendencies of accident drivers to be bad in scores of them both, and of non-accident drivers to be good in both. On the other hand, with respect to those whose scores are bad (or good) either in counting or in error reaction, they had such tendencies that the accident drivers become bad in error reaction and non-accident drivers remain good in it. From these findings it may be expected that accident drivers were apt to be disturbed by new tasks or absorbed too much in them, not being able to pay adequate attention to the task in which they have been engaging, in other words, the fretful or hasty reactions found in the accident drivers seem to be due to the weakness in the function of inhibition in their brain mechanism, as Maruyama[2] hypothesized.

It was our final purpose to contrive an effective test battery for detecting accident proneness of a motor driver or of those who wish to be driver. In this connection, the test described here could be regarded as a useful measure of it. Most of the indexes of the test showed high efficiency ratio: 73.1 % for the index of error reaction in Part II, 65.8 % for the combined index of error reaction and coefficient of variation in Part II, etc. Besides, there were more indexes which would prove to be useful as test index, if only the problem of limit of qualification were solved.

Now, the relationships between this test and the Speed Anticipation Test will be mentioned briefly. Each of the two tests had a high efficiency ratio and proved to be useful by itself. How will be the effectiveness be, however, when the two tests are combined? The result of the combination showed an efficiency of 82.5% ($\chi^2=17.136$, $df=3$, $p<.01$).

Table 17

Qualification / Group	Qualified drivers	Disqualified drivers
NAG	12	5
SG	7	6
IG	7	8
AG	2	21

Result of discrimination by the two tests was shown in Table 17. This indicates that a test battery consisting of Discriminative Reaction Test of Multiple Performance Type and Speed Anticipation Test is a fairly good one for the discrimination of motor drivers.

Lastly, it will be neccessary to say a word about the correlation among the indexes of two types of tests. From the Table 18 the following considerations can be done.

(1) According to ϕ, there was little relationship among two types of tests, i. e., each test discriminated each different group of Ss.

(2) According to the correlation r, there is no relationrhip between $\overline{X}$ and V in each test. Only the $\overline{X}$ within the Discriminative Reaction Time Test has a positive relationship. It was considered that a little modification of the test procedure would turn into an entirely different sort of test, and that each index of our test is different in essence.

Table 18

Correlations between test indexes

(1) Degrees of association (ϕ) with regard to the discrimination of drivers according to the criterion.	
(a) Between error reaction and coefficient of variation in Part I, combined with those in Part II	0.060
(b) Between error in Part II (with buzzer and without buzzer) and the mean auticipation time in Speed Anticipation Test	
(i) Where the category of ? group was included	0.252
(ii) Where the category of ? group was excluded	0.141
(2) Mean reaction time (r)	
(a) Between Part I and Part II	+0.651
(b) Between Part I and S. A. T.	−0.387
(c) Between Part II and S. A. T.	+0.088
(3) Coefficient of Variation (r)	
(a) Between Part I and Part II	−0.118
(b) Between Part I and S. A. T.	+0.056
(c) Between Part I and S. A. T.	+0.277

Summary

Results of application of a new test to motor drivers in a bus company were reported. The "Discriminative Reaction Test of Multiple Performance Type" was prepared with the purpose of discriminating accident drivers more distinctly from non-accident drivers than before. The test was chiefly concerned with the coordinative function of perception and motor reaction. And, from the present test, the fretfulness in reaction of accident drivers was found as had

been hitherto pointed out by many investigators. Accident drivers had a tendency to be short in reaction time and to make many errors, too. This tendency became more remarkable as the complexity of the task situations increased. It was observed also that an accident driver tended to be disturbed by a new task or absorbed too much in it, and that if the new task was imposed on him, he could not pay any adequate attention to the task in which he had been engaging. These fretful or hasty reactions in the accident drivers were considered to be due to the weakness in the function of inhibition in their brain mechanism.

It was ascertained that efficiency ratio of discrimination of the test was so high that the test could be used as a measure of detecting accident prononess of drivers, and that the ratio became higher, if the test was used in combination with the Speed Anticipation Test.

The correlation among the indexes in this test as well as that between this test and Speed Anticipation Test was discussed.

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Zusammenfassung

Um die besonderen Eigenschaften des Autofahrers, der Verkehrsunfälle herbeigeführt hat, mit denselben des verkehrssicheren Autofahrers zu vergleichen, wurde eine Auswahlprüfung (ein aus mannigfaltigen Aufgaben bestehendes Wahlreaktionsexperiment) für 69 Autofahrers ausgeführt.

Es gelang dabei, folgende Ergebnisse zu erzielen.

Beim Unfälle-Autoführer, (1) war zwar die kürzere Reaktionszeit, aber zugleich mehr Fehler-Reaktionen, d. h., mehr hastige Reaktionen erkennbar, und es stellte sich heraus, (2) dass er durch eine unterdrückende Aufgabe, in der die Vp. für vier den Summer begleitende Reizen unter 16 Reizen nicht reagieren darf, mehr beeinflüsst wurde, d. h., die Häufigkeit der Fehler-Reaktion bei ihm grösser wurde.

Durch solches Merkmal konnte man die verkehrssicheren Autofahrer von den nicht sicheren Führern ziemlich scharf unterscheiden.

Das Verhältnis zwischen dieser Prüfung und der "Prüfung der Geschwindigkeitserwartung" wurde diskutiert.

Résumé

En vue de comparer les caractères des chauffeurs accident-faits et non-accident-faits, une épreuve du temps de réaction discriminative avec la tâche multiple a été administrée aux chauffeurs d'autobus. Nos résultats sont si suivants:

1) Les sujets du groupe accident-fait eurent une tendance à accélérer la rapidité de réaction et à augmenter le fréquence des erreurs plus que les autres; cela signifie la tendance de réaction précipitante.

2) Les sujets du groupe accident-fait furent susceptibles d' être affectés par les stimuli d'obstacles et la tâche multiple.

A la fin, la relation entre cette épreuve et l'épreuve de la vitesse d'anticipation a été discutée.