INTERACTION OF TWO SIGNAL SYSTEMS IN NORMAL AND SCHIZOPHRENIC INDIVIDUALS*

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INTRODUCTION

In previous studies (Takata, 1959, 1960), the writer has showed that both discrimination of frequency difference of the sound stimulus and discrimination of inclination difference of the light stimulus were special functions of the interaction of the first and the second signal systems. The former was believed to be a function of the signal transmission from the first to the second signal system but in the latter the second signal system was shown to play a predominant function over the first signal system. These results were obtained from our conditioning experiment (Takata, 1959) and from a study on the relations between stimulus discrimination and personality traits.

These two studies were an attempt to classify stimulus materials in terms of the signal systems as well as an attempt to determine typological peculiarities of the higher nervous activities of the human subjects by theory of conditioned reflexes, especially in terms of the signal systems.

In USSR, attempts have been made to find the way to classify types of the higher nervous activities and to find peculiarities of the interaction of the two signal systems in human subjects by the method of con-

ditioning. In these attempts the direct (non-verbal) stimulus and the verbal stimulus have always been used to test peculiarities of the second signal system in interaction with the first signal system.

If expansion of the function of the second signal system activity to other direct stimuli is possible, it would be a new method in the field of perception as well as in conditioned reflex.

Pathological peculiarities of schizophrenic patients concerning the interaction of the signal systems were characterized by disturbances of the two signal systems particularly by these of the second signal system in its interaction with the first signal system.

The purpose of this study is to see if similar conclusions can be obtained with schizophrenic patients to those with normal subjects mentioned above. For this purpose two experiments were conducted to examine relationships between stimulus discrimination and conditioning.

EXPERIMENT I

Method

Experiment I was designed to compare the relationship between visual and auditory discriminations in normals and schizophrenic patients.

Apparatus.—*S* was seated at a table in a dark room with his chin supported by an adjustable chinrest. Sound pressure levels of the tones were about 50 db. The light stimulus was an illuminated straight line of 50 cm in length and 5 mm wide and presented 2 meters before *S*.

Subjects.—Twenty students (14 male, 6 female) in the Department of Psychology,

* The author is greatly indebted to Mr. R. Takagi, Assistant of the Department of Neuropsychiatry, Kyoto Univ., for his helpful assistances and advices in the execution of experiments. In addition, the author wishes to thank Mr. S. Iwahara, Assistant Professor of Nara Women's Univ., for his kindness in editing English phraseology.

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Kyoto Univ. served as a normal group. Twenty patients, (11 male, 9 female), 19 to 40 years old, diagnosed by psychiatrists as schizophrenia were used as a schizophrenic group. These schizophrenic Ss were chosen from the patients in the Neuropsychiatric Ward in the Hospital of Kyoto University bearing the diagnosis of chronic schizophrenia and their case materials did not indicate cerebral organic involvements. Out of 20 Ss 16 were diagnosed as the hebephrenic type, 1 as the paranoid type and 3 as the chronic undifferentiated type.

Procedure.—Lower differential thresholds (80–90% correct response) were measured of the visual and auditory stimuli by the modified method of limits. In the auditory task, the standard stimulus was 1200 cps and comparison stimuli were sounds of lower cps. The visual task was an inclination discrimination of a slant line; the standard stimulus was a line inclined 60° from the horizontal line and the comparison stimuli were lines less inclined. The duration of each stimulus was 1 sec. and the intertrial interval was about 10 sec. Order of presentation of the visual and auditory tasks was reversed for half of the Ss.

Results and Discussions

Table 1 shows the relationship between visual and auditory discriminations in normals and schizophrenic patients. In schizophrenic patients the lower differential thresholds of both visual and auditory stimuli were greater than the normal group. Particularly auditory discrimination in schizophrenic patients was much worse than in visual discrimination as compared with those in normal subjects,

and the individual differences were also greater in patients.

In previous studies (Takata, 1959, 1960), the writer has showed that the frequency discrimination of the sound was influenced in the signal transmission from the first (direct) signal system to the second (verbal) signal system or more exactly in the process of the interaction of the two signal systems and that the inclination discrimination of a line was mainly a function of the abstracting and generalizing activities of the second signal system.

In one of these studies the writer obtained clear correlations between the stimulus discriminations (the same materials as in the present study) and the personality traits measured by the Yatabe-Guilford personality inventory in normal subjects. In discrimination of frequency differences, *emotionally unstable* subjects (with high scores on Depressive, Cyclic, Inferior, Nervous, and Subjective traits) tended to show worse discrimination with high sound stimuli and *thinking-introvert* subjects (with high T scores) responded to all visual inclined stimuli as “near vertical” more often than did thinking-extrovert Ss.

The emotional stability factor is closely connected with the functions in the interaction of the two signal systems and the thinking-introvert personality trait was largely concerned with the characteristic action of the second signal system. The lines used were about 60° inclined and these were the stimuli to be judged “near vertical” rather than “near horizontal” as only these two judgements were allowed.

According to the theories and experimental findings on conditioned reflexes in USSR (Ivanov-Smolensky, 1954), the higher nervous activities of schizophrenics were characterized by the disturbances of the first and the second signal systems and particularly of the second signal system in its interaction with the first signal system. The present experimental findings confirmed these neuro-dynamic peculiarities in

Table 1

Lower differential thresholds (80–90% correct response) of sound pitch and the visual inclination of a line in normals and schizophrenics.

Group		Schizophrenia (<i>N</i> = 20)	Normal (<i>N</i> = 20)
auditory stimulus (in cps)	<i>M</i>	101.0	15.7
	<i>SD</i>	64.7	4.7
visual stimulus (in degrees)	<i>M</i>	6.7	2.7
	<i>SD</i>	2.6	0.3

schizophrenia, that is, frequency discrimination, the function of the signal transfer from the first to the second signal systems was much worse in schizophrenic patients.

EXPERIMENT II

This experiment was conducted to see the relationship between stimulus discrimination and conditioned reflex characteristics in normals and schizophrenics.

There are many reports and publications in Russian laboratories about conditioning studies of schizophrenia.* The disturbance of the conditioned-unconditioned, conditioned-conditioned and the cortical-subcortical connections, and the disturbance between the interactions of the two signal systems have been found in these studies. The present experiment was mainly concerned with the signal peculiarities in schizophrenic patients by the conditioning method.

Method

Apparatus.—The apparatus for presenting conditioned stimuli was the same as in Experiment I. The equipment for recording conditioned responses was Takei's electrical polygraphic recording apparatus, by which mechanical movements of the bulb-pressing response could be recorded. UCS was an electric shock to the left hand, controlled by a valuable resistor. A 25-volt dry battery was used as a source of the shock.

Subjects.—Seven male students from the Department of Psychology, Kyoto University served as a normal group. As a schizophrenic group, 9 hospitalized chronic patients (5 male, 4 female) were used. Out of nine, 7 were diagnosed as the hebephrenic type and 2 as the chronic undifferentiated type. They were selected at random from the schizophrenic patients used in Experiment I.

Procedure.—As a conditioned response, motor reaction was used. *S* could avoid the electric shock (UCS) if he kept pressing a bulb while

UCS was operant. That is, if *S* failed to press the bulb for a certain period after termination of CS, he would receive shock. The minimal discriminable difference between a positive CS(CS⁺) and a negative CS(CS⁻) was determined. The method for measuring differential thresholds was the same as in Experiment I.

The differential conditioning procedure was then used with the obtained minimal difference (80–90% correct) between the two CSs. The duration of the CS was 2 sec. and the UCS appeared when the CS terminated. The duration of UCS was 0.5 sec. The intensity of the shock varied slightly between *Ss* so that the shock was not very painful. Intertrial interval was 15 sec. The experiment was conducted on two days to see practice effects of conditioning. The second day experiment was conducted 1 to 4 days after the first-day experiment. In each day's experiment 15 CSs⁺ and 15 CSs⁻ were presented and their orders of presentation was so prearranged that no more than three CS⁺ or CS⁻ trials occurred in succession. CSs were the same as the stimulus materials in Experiment I and visual and auditory stimuli were paired as a simultaneous stimulus compound.

The positive visual stimulus was a straight line 60° inclined from the horizontal line and the negative stimulus was a line less inclined. The positive auditory stimulus was a 1200 cps tone and the negative stimulus was a tone of lower cps.

Ss were asked to report about the nature of the conditioned stimulus after termination of each conditioning trial. The required verbal reports were either that the positive visual stimulus was "near vertical", and the negative stimulus was "near horizontal": the positive auditory stimulus was "high", and the negative stimulus was "low".

Results and Discussions

Table 2 showed the lower differential thresholds of both stimuli on the first and the second day experiments. In some patients changes of the thresholds were observed on the second day; some showed better differentiation and some worse (changes were 40–200 cps in frequency and 2–5 degrees in inclination). But in

* They are mainly in Журн. Высш. Нервн. Деят., Труд. Ин-та Физиол. Павлова., Труд. Ин-та Высш. Нервн. Деят. Патофизиол. серия.

Table 2

Lower differential thresholds (80–90%) in visual and auditory tasks in normals and schizophrenics on the first and the second day experiment.

Group	Schizophrenia (<i>N</i> =9)			Normal (<i>N</i> =7)	
	DAY	<i>M</i> (%)	<i>SD</i>	<i>M</i> (%)	<i>SD</i>
auditory stimulus (in cps)	1	148.9	84.3	13.0	3.6
	2	144.4	94.7	13.0	3.7
visual stimulus (in degrees)	1	7.0	2.1	2.6	0.2
	2	7.2	3.5	2.6	0.2

Table 3

The relations between stimulus discrimination and motor response differentiation during conditioning.

Group	Schizophrenia (<i>N</i> =9)			Normal (<i>N</i> =7)	
	DAY	<i>M</i> (%)	<i>SD</i>	<i>M</i> (%)	<i>SD</i>
visual discrimination	1	69.6	21.8	61.6	29.4
	2	74.8	34.8	78.0	23.6
auditory discrimination	1	22.2	49.6	58.0	29.6
	2	57.0	40.4	64.6	24.4
motor differentiation	1	24.4	33.5	47.6	30.6
	2	37.6	47.8	57.2	30.6

The mean percentage of the total discrimination (differentiation) was measured by the mean correct response percentage in units of five positive (CS⁺) trials minus mean incorrect* response percentage in units of five negative (CS⁻) trials.

first day auditory discrimination normal > schizophrenia Cochran-Cox $t=1.96$ $t_{.10}=1.87$
 first day motor differentiation normal > schizophrenia $t=1.84$ $df=14$ $p<.10$
 auditory discrimination (schizophrenia) second day > first day $t=2.23$ $df=8$ $p<.06$
 visual discrimination (normal) second day > first day $t=2.78$ $df=6$ $p<.05$

* In CS⁺ trials CRs were counted as correct responses, and in CS⁻ trials CRs were as incorrect responses.

most cases, the changes of the auditory discrimination were accompanied by the changes of the visual to the same direction. In normal subjects these day-to-day variations were not observed.

Table 3 showed that auditory discrimination during conditioning and the motor differentiation was better in normals than in schizophrenic patients on the first day. As was shown previously in Experiment I, the disturbance of the frequency discrimination was the patho-dynamic peculiarities of the higher nervous activities in schizophrenia, which were characterized by the disturbance of the signal transmission

from the first to the second signal systems.

The disturbance of the auditory discrimination during conditioning in Experiment II could be explained in the same way. The lower motor differentiation was also shown as the result of the disturbance in forming new conditioned connections.

In normal subjects visual discrimination during conditioning on the second day was better than that on the first day. In schizophrenic patients, on the contrary, the second-day auditory discrimination during conditioning was better than the first, although the differential threshold

Fig. 1. The relations between stimulus discrimination and response differentiation during conditioning.

was the same as was the first-day discrimination.

Samsonova (1955 a, b, c, 1956) showed that in conditioning, when the stimulus and the response materials coincided in the signal system activity characteristics*,

* Responses are classified: 1) involuntary response, i.e., the first signal system activity, 2) semi-voluntary response, i.e., mixture of the first and the second signal system activities, 3) voluntary response, i.e., under the direct control of the second signal system, and 4) verbal response, i.e., the second signal system activity. Likewise, the stimulus materials can be classified in the same way as the responses.

the discrimination (differentiation) was worse in the early period of conditioning than the dissimilar stimulus-response connections but after the repeated application of the conditioning procedure, the former became to be better discriminated (differentiated) than the latter.

In previous experiments (Takata 1959), the writer showed that visual discrimination of inclination had the same function as the bulb-pressing motor response with respect to the peculiarities of the signal system activities, i.e., in both of them the second signal system was largely predominant.

Comparing the experimental findings of Samsonova with the present writer's, one may at once notice that normals showed the better visual discrimination during conditioning on the second day than the discrimination on the first day because the inclination difference had the same signal function as the motor response under the predominance of the second signal system.

Then how the present experimental results in schizophrenic patients which showed improvement in auditory discrimination during conditioning from the first day to the second day, can be explained? The auditory task in schizophrenic patients seemed to have similar functions as the visual task in normals in relation to the motor response connection.

This may be explained in terms of the disturbance and disorganization of the higher nervous activities in schizophrenic patients (especially the activities of the second signal system with respect to its interaction with the first signal system as shown in the auditory task).

The following results may support our explanation. In a hebephrenic patient TON who had been in hospital for more than ten years tended to report all auditory stimuli as low sounds when they were paired with the visual or the motor task. An analogous result was obtained in a long-hospitalized hebephrenic patient TOM. In both cases their positive motor response

was characterized by very lower responding rates.

Together with the disturbances in the auditory discrimination and disturbances in the stimulus-motor connection shown in all schizophrenic patients which we mentioned above, the lower discrimination in the "high sound stimulus condition" in patients TON and TOM confirmed the theories and many experimental findings of the conditioned reflexes in schizophrenic patients.

In schizophrenia the degree of the disturbances observed in the stimulus discrimination and in the stimulus-response connections varied from time to time. Although drug effects on conditioning were not studied in the present study, these changed in degree of the disturbances might be considered to show the pathological states between patients as well as those within them. In these connections, an intensive survey of the peculiarities of these disturbances in the different stages of the pathological states of one patient is necessary.

In some schizophrenic patients, various forms of paradoxical and ultra-paradoxical phases were observed during the course of conditioning. These were characterized by the disturbances in the functions of the auditory task (paradoxical phase) and, in some cases, the negative stimulus produced greater CRs than the positive stimulus (ultra-paradoxical phase).

In determining the differential thresholds of the visual and auditory stimulus, S's verbal report about the nature of the stimuli was substituted for the motor task, where the subject was instructed to respond by pressing the bulb to one stimulus (e.g., a high sound) and not to respond to another stimulus (e.g., a low sound).

Substitution of verbal responses for motor reactions led to sudden changes and disturbances in the sensitivity of the two

analysers, some to the better and some to the worse. In normal subjects these sudden changes were not observed. In the writer's previous study in auditory discrimination with normals in some conditions *emotionally unstable** subjects responded correctly in motor reports more often than in verbal reports and *emotionally stable** subjects showed reverse results. The analogous phenomena were not observed in schizophrenic patients.

SUMMARY

Two experiments were conducted to investigate stimulus discrimination and response differentiation in normals and schizophrenic patients.

Disturbances both in stimulus discrimination and response differentiation were observed in schizophrenic patients but not in normals. An attempt was made to connect the peculiarities of those disturbances in schizophrenic patients with those in normals obtained in conditioning and in the correlation to the personality traits.

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* These personality traits were tested with the Yatabe-Guilford inventory.

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(Received June 11, 1960).