Ann. Bull. RILP (1982) No. 16, 143-164

DICHOTIC DETECTION TASKS AND SCHIZOPHRENIC ATTENTIONAL DEFICIT

Shin-ichi Niwa, Ken-ichi Hiramatsu*, Tomomichi Kameyama*, Osamu Saitoh*and Kenji Itoh*

Many authors in the field of experimental psychology have conducted research on the various psychological aspects of schizophrenia. One of the main streams in that field is concerned with schizophrenic attentional deficit as reflected in terms of reaction time. Many hypothetical models concerning schizophrenic attentional deficit have been drawn from reaction time studies: e.g., abnormality of mental set hypothesis (Shakow, 1962); dysfunction of selective filter hypothesis (McGhie, Chapman & Lawson, 1965; Payne & Caird, 1967); redundancy-associated deficit model (Bellissimo & Steffy, 1972). These models were made with the intention of explaing the schizophrenic attentional deficit in terms of an abnormality in the sensory processing system of schizophrenics and, subsequently, in terms of brain mechanisms. An example of this approach is McGhie's hypothesis concerning the dysfunction of selective filtering, which is based upon Broadbent's model of selective filtering in the sensory processing system of humans. Since the sensory processing theory has made such great progress recently, it has come to be more widely accepted when applied to studies on schizophrenic attentional deficit. An example of this is reflected in the reaction time study on schizophrenics conducted by Wishner, Stein & Peastrel (1978), in which Sternberg's paradigm (Sternberg, 1969) was employed.

On the other hand, many studies utilizing a neuropsychological approach to study the pathophysiology of schizophrenia, and hence, their brain mechanisms, have been carried out, especially within the past ten years. Examples utilizing this neuropsychological approach include the following: Beaumont & Dimond (1973); Gur (1978); Lerner, Nachson & Carmon (1977). These studies utilizing a neuropsychological approach were based upon developments in the 1960's in the field of neuroscience and neuropsychology, as cited specifically in studies concerning cerebral lateralization in split-brain patients conducted by Sperry (1968), and studies concerning the "disconnection syndrome" conducted by Geschwind (1965). All previous neuropsychological studies of schizophrenics regarding cerebral functioning have suggested that 1) schizophrenics demonstrate left hemispheric dysfunction; and 2) schizophrenics display a disturbance in the integration of both cerebral hemispheres.

It was felt that a combination of the seosory information processing theory and neuropsychological studies of schizophrenics might result in an effective approach to investigating the pathophysiology of schizophrenia.

* Department of Neuropsychiatry, Faculty of Medicine, University of Tokyo

In this study, schizophrenics were required to perform a vigilance task (signal detection task) under special conditions in which one of the cerebral hemispheres was selectively activated. This method was used as a means of clarifying the relationship between the schizophrenic attentional deficit and the above mentioned neuropsychological findings. To be more specific, schizophrenics were required to listen to dichotically-presented non-verbal sounds and to press a response key upon detection of a particular target sound presented to one ear (dichotic detection task). This experiment yielded reaction times and percentages of correct responses which were employed as indexes in examining the ability of each cerebral hemisphere to perform the vigilance task.

It has already been shown that each of the cerebral hemispheres can be selectively activated (Kinsbourne, 1975; Trevarthen, 1962). In this experiment, a modified dichotic listening method was employed as a means of activating each of the cerebral hemispheres. The dichotic listening test devised by Kimura (1961) and the one which was employed in this study, were the same in that the sound presented to one ear was transmitted almost exclusively to the opposite side of the cerebral hemisphere. Springer (1971) conducted an experiment employing the same dichotic detection method employed in this experiment, and ascertained the effectiveness of this method in examining each ear's ability in detecting target sounds.

It was felt that this study would provide a new method in investigating the psychopathology of the attentional deficit in schizophrenics by combining reaction time studies and neuropsychological studies.

Method

Subjects

Subjects consisted of schizophrenic patients (5 males, 6 females) randomly selected from a group of schizophrenic patients under treatment at the Neuropsychiatric Outpatient Clinic, Tokyo University Hospital. All patients met the criteria for the diagnosis of schizophrenia according to the RDC (Research Diagnostic Criteria) classification system. The ages of the patients ranged from 22 to 65 years (mean age: 31.6 years), and all patients, excluding two (S3 and S5), had been engaged in psychotropic drug therapy. Further details concerning the patients are presented in Table 1. Eleven normal subjects, closely matched in age to the patients, served as the control group. Normal controls consisted of 6 males and 5 females, with ages ranging from 21 to 68 years (mean age: 32.3 years). None of the normal controls had any previous history of psychiatric or neurological disease. Further details concerning the normal controls are presented in Table 2. All of the patients and normal controls were right-handed and were found to be free from any hearing disability.

Procedure

As previously mentioned, the purpose of this study was to examine each cerebral hemisphere's ability to perform the vigilance task. To achieve this purpose, a dichotic detection task was employed in this study. That is, participants were required

CASE NO.	CASE	AGE	SEX	MEDICATION(mg)
S1	S.S.	23	F	SUL 600
S2	M.O.	29	M	CP 112.5, HPD 2.25
S3	Y.S.	29	F	none
S4	K.M.	23	M	CP 50, TTX 10
S5	H.I.	65	M	none
S6	T.K.	27	M	CP 100
S7	C.W.	22	F	CP 150
S8	E.F.	43	F	CP 150, HPD 6.75
S9	K.T.	27	F	CP 200, HPD 2.25
S10	K.K.	38	M	CP 75, HPD 3
S11	N.H.	22	F	HPD 3, PZ 2

CP:chlorpromazine,TTX:thiothixene,
HPD:haloperidol,PZ:pimozide,
SUL:sulpiride

Table 1 *The schizophrenic subjects employed in the study*

CASE NO.	CASE	AGE	SEX
N1	T.S.	30	F
N2	T.O.	28	M
N3	H.A.	31	F
N4	K.Y.	22	M
N5	Y.A.	68	M
N6	S.N.	33	M
N7	Y.U.	21	F
N8	K.K.	42	F
N9	J.A.	22	F
N10	Y.O.	37	M
N11	J.K.	21	M

Table 2 *The normal control subjects employed in the study*

to listen to dichotically-presented non-verbal sounds and to press a response key upon detection of a particular target sound presented to one ear, thus yielding reaction times and percentages of correct responses.

The stimuli consisted of four non-verbal sounds, which are shown schematically in Fig. 1. Each stimulus consisted of a frequency-modulation sound (FM sound) which lasted 50 msec and a frequency-constant sound (tone burst) which lasted 100 msec. The total duration of each stimulus was 150 msec. The four stimuli were paired on the basis of equal constant frequency, that is, the "1 kHz" pair, shown on the left, and "500 Hz" pair, shown on the right in Fig. 1. Each pair of stimuli was presented to each ear during a session. The two sounds in the upper part of Fig. 1 were presented more frequently, with a priori probability of .8, than the two sounds in the lower part, with a priori probability of .2. The infrequent stimulus in each pair of sounds was to be detected, that being the "target stimulus".

These various stimuli sounds were composed and tape-recorded at the Research Institute of Logopedics and Phoniatrics, University of Tokyo. In the experiment, the tape-recorded stimuli were presented through a pair of headphones to the participants. The inter-stimulus intervals were of 2 sec duration. The tone intensities were approximately 50 dB SL. As shown in Table 3, this experiment consisted of eight sessions (two target stimuli [500 Hz, 1 kHz] x two sides for the attended ear [left, right] x two sides for the response hand [left, right]). The order of the eight sessions is also shown in Table 3. Just prior to the dichotic detection task, the participants were required to perform monaural detection tasks. That is, the sounds of the 500 Hz pair were presented to one ear and the subjects were required to detect the target stimulus and to press the response key. The purpose of this task was to obtain data which could then be used as a standard against which the results of the dichotic detection task could be compared. This monaural detection task consisted of four sessions (two sides for the attended ear [left, right] x two sides for the response hand [left, right]). The order of the four sessions was as follows: 1) right ear, right hand; 2) left ear, right hand; 3) right ear, left hand; 4) left ear, left hand. The interval between two successive sessions consisted of a five-minute resting period; and in the case of the dichotic detection task, the interval between the 4th and 5th sessions consisted of a ten-minute resting period. Practice sessions were held prior to the monaural detection task and dichotic detection task, and during this time all participants were expected to attain a score of more than 50% correct responses. In each experimental session, the presentation of the stimuli was continued until the number of correct responses reached 30. The experimental sessions were conducted in the afternoon.

In the experiment, the participants wore eye masks so as to eliminate visual stimuli. The finger for pressing the response key was the index finger of either hand. The response key was located immediately in front of the participants. The participants were asked to rest the appropriate index finger on the response key and to press the key upon detection of the target stimuli.

Reaction times were measured with a digital timer (degree of accuracy within 1 msec) which was triggered by a square pulse. This square pulse was synchronized with the presentation of the stimulus. The stimulus sounds, the timer-triggering pulses, and the key press reponse pulses were recorded on a polygraph, and the

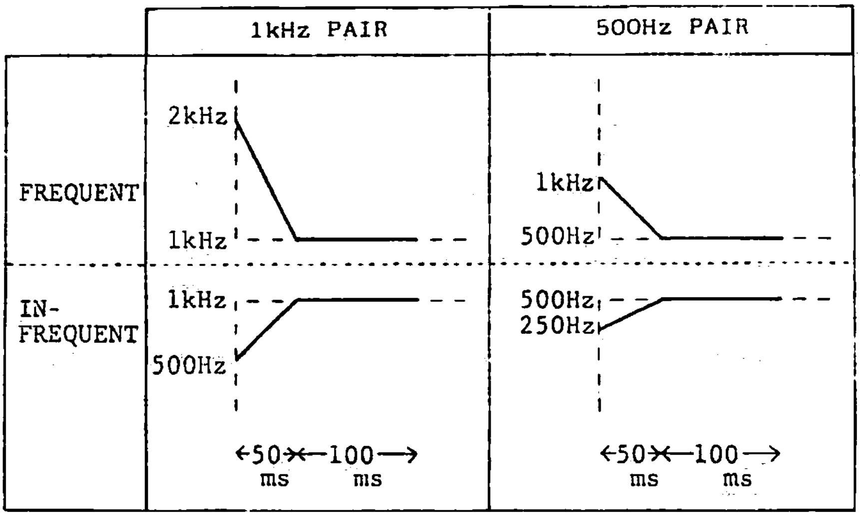

Fig. 1 *Schemata of the stimuli*

attended ear \ response hand	right	left		left	right
right (500Hz)	1	3	left (500Hz)	5	7
left (1kHz)	2	4	right (1kHz)	6	8

Table 3 *Experimental sessions for the dichotic detection task (The numbers in the table indicate the order of the sessions.)*

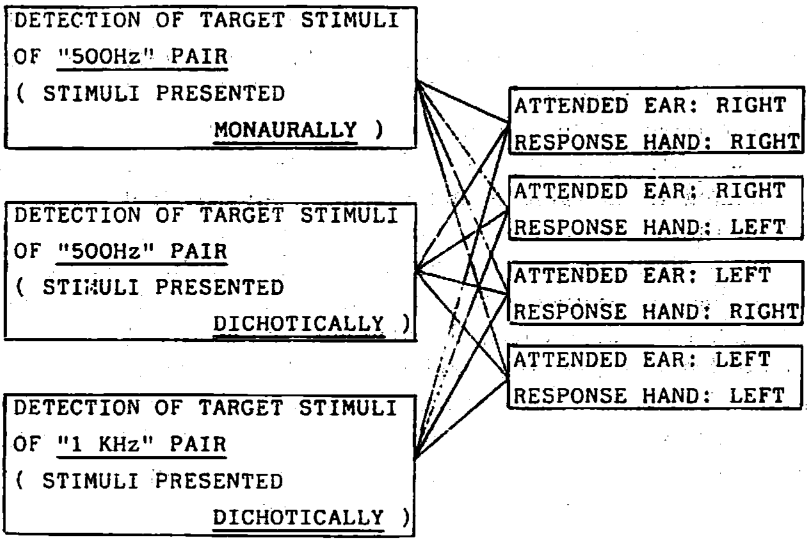

Table 4 *Summary of the tasks required in the study*

polygram was then used as a monitor to check the correctness of the participants' responses. Reaction times measured by the digital timer were recorded on a digital printer. The experimental apparatus used in this study consisted of the following: Tape recorder, TC-2500, SONY; Audio pre-amplifier, A-004, PIONEER; Headphones, YH-5M, YAMAHA; Digital timer, TW7010A, TAKEI KIKI; Digital printer, DP310, UNITEC DENSHI.

This experiment yielded data on reaction times and percentage of correct responses for 12 sessions (Table 4). In the following analyses of the results, the reaction time for each session was represented by the mean of the reaction times of the correct responses. The percentage of correct responses was calculated in the following manner: (number of correct responses/number of target stimuli) x 100. The ability to perform the vigilance task in each of the 12 sessions, as shown in Table 4, was examined using the reaction times and the percentage of correct responses as indexes.

Results

Analysis of the reaction time data

This experiment yielded twelve sets of reaction time data for each participant. Each set of data consisted of reaction times for 30 correct response trials. The reaction times for each session for each subject were represented by the mean of the reaction times for 30 correct response trials. Prior to obtaining the mean of the reaction times, the distribution of the reaction times was examined, and it was found that this distribution tended to be asymmetrical in shape and tended to peak in the shorter reaction time ranges in patients as well as in normal controls (Fig. 2). Following these results, the reaction times were first transformed into logarithms, yielding also, the mean of the logarithms. These means were then re-transformed into reaction times, indicated in terms of msec. The mean reaction times and the standard deviations of 11 patients, as well as those of 11 normal controls, for each session, are shown in Table 5. The mean reaction times of patients, as well as normal controls, are plotted in Fig. 3. The terms, 'MONAURAL', 'DICHOTIC ("500 Hz")', and 'DICHOTIC ("1 kHz")' in Table 5 and Fig. 3, designate the task of detecting the 500 Hz pair target stimuli from dichotically presented stimuli; and the task of detecting the 1 kHz pair target stimuli from dichotically-presented stimuli, respectively. Judging from Table 5 and Fig. 3, it appears that patients exhibited slower reaction times than normal controls in every task. To examine the results statistically, an analysis of variance concerning the reaction time data was conducted considering the following five factors: 1) group category (patients/normal controls); 2) individual differences; 3) sidedness of the attended ear; 4) sidedness of the response hand; and 5) the required task. A split plot design was employed in the analysis of the data. The first order factors consisted of group category and individual differences. The second order factors consisted of the sidedness of the attended ear, the sidedness of the response hand, and the required task. The analysis of variance results are presented in Table 6. Group category, individual differences, the required tasks, and (group category x the required tasks) were found to have a significant influence on the results ($p < .01$). The means for the mean reaction

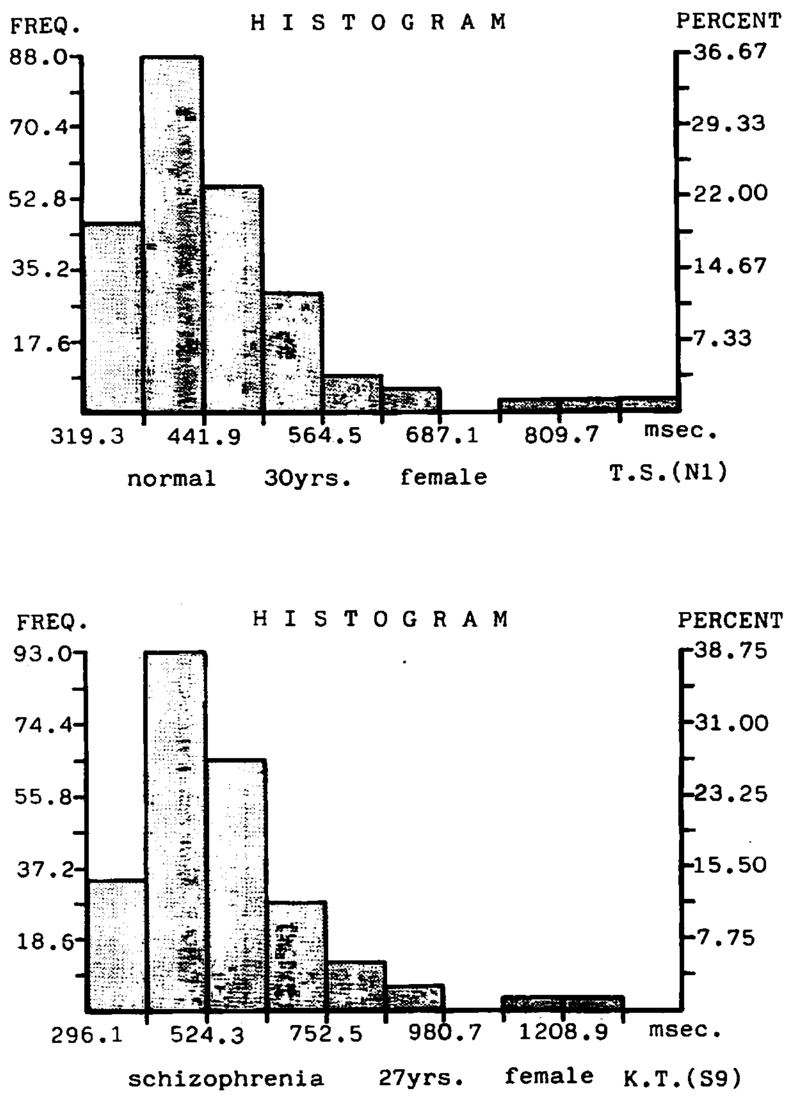

Fig. 2 *Distribution of reaction times*

		LE —— LH	LE —— RH	RE —— LH	RE —— RH
Normal Control (n=11)	Monaural	279.72 ± 69.09	291.37 ± 62.01	295.22 ± 71.23	289.30 ± 61.12
	Dichotic(500Hz)	350.24 ± 89.31	341.96 ± 79.08	362.73 ± 79.77	359.14 ± 74.80
	Dichotic(1kHz)	406.44 ± 96.81	443.15 ± 101.17	410.95 ± 87.19	381.34 ± 89.99
Schizophrenia (n=11)	Monaural	433.00 ± 126.21	458.91 ± 128.19	458.03 ± 111.03	448.16 ± 93.29
	Dichotic(500Hz)	484.27 ± 118.13	482.50 ± 113.74	501.84 ± 101.86	528.97 ± 125.84
	Dichotic(1kHz)	535.79 ± 119.85	551.61 ± 131.12	555.68 ± 144.57	549.18 ± 148.98

Table 5 *Mean reaction times for each task for schizophrenics and normal controls*

LE: left ear; LH: left hand; RE: right ear; RH: right hand

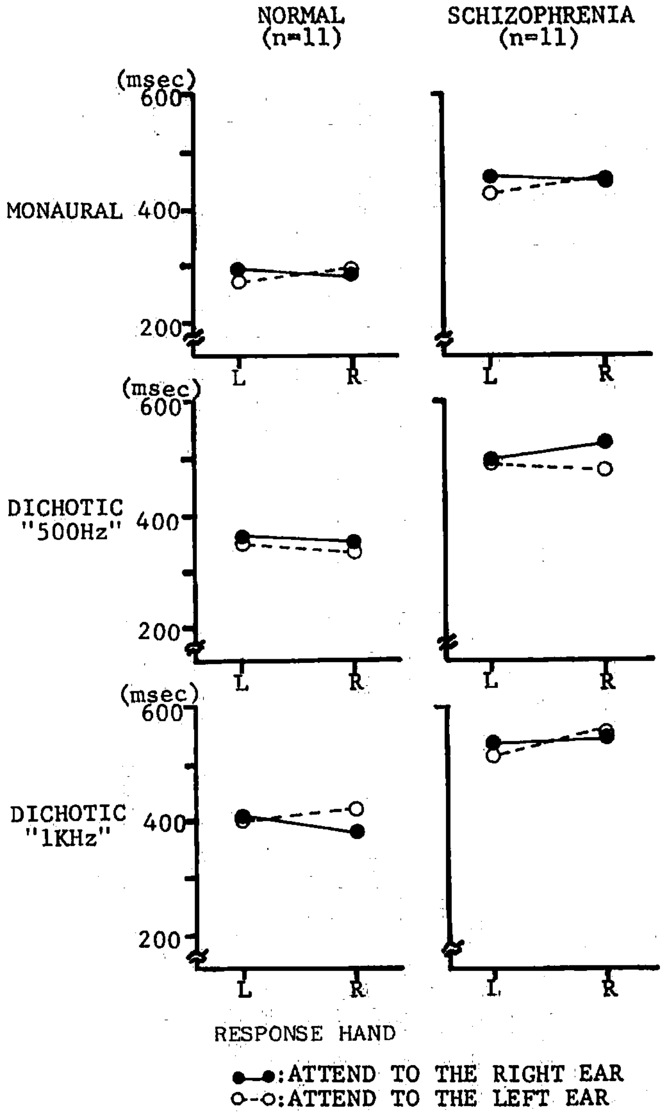

Fig. 3 *Mean reaction times for each task for schizophrenics and normal controls*

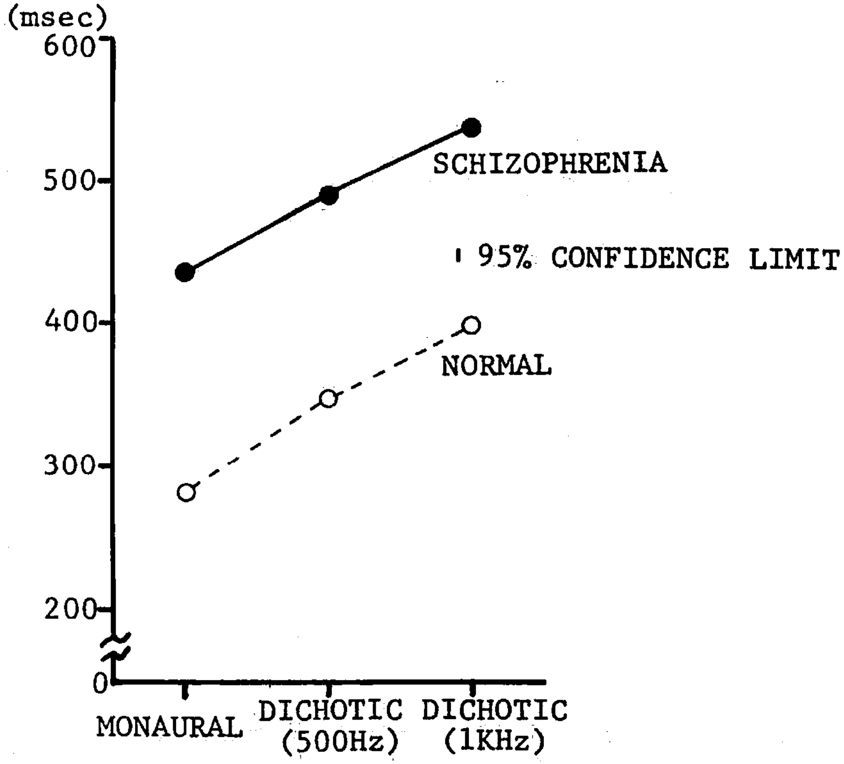

Fig. 4 *Mean reaction times for each task for schizophrenics and normal controls. In this figure, the data for both ears and both hands are combined.*

times of patients and normal controls from Fig. 3 were then obtained and plotted, as shown in Fig. 4. The means, expressed in msec, for the mean reaction times of patients and normal controls on each task are as follows: MONAURAL, 437, 282; DICHOTIC 500 Hz, 490, 347; DICHOTIC 1 kHz, 537, 398. Judging from Fig. 4, the analysis of variance results indicate the following: 1) Patients exhibited slower reaction times than normal controls on every task. 2) Patients, as well as normal controls, displayed a progressive increase in mean reaction time from MONAURAL to DICHOTIC 500 Hz to DICHOTIC 1 kHz. 3) In normal controls, the difference in reaction times between the MONAURAL and DICHOTIC 500 Hz tasks was greater than between DICHOTIC 500 Hz and DICHOTIC 1 kHz; while in patients, the difference between these respective tasks was essentially equal (MONAURAL to DICHOTIC 500 Hz, DICHOTIC 500 Hz to DICHOTIC 1 kHz). 4) Comparing the MONAURAL and DICHOTIC 500 Hz tasks, normal controls displayed a greater difference in reaction times than patients; however, comparing the DICHOTIC 500 Hz and DICHOTIC 1 kHz tasks, there seemed to be no significant difference in reaction times between patients and normal controls. Thus, patients were found to differ from normal controls concerning the pattern of their reaction time changes, as represented in Fig. 4.

In addition, the analysis of variance revealed no significant difference in terms of reaction time between the dominant hand and nondominant hand tasks. There also appeared to be no significant difference concerning the sidedness of the attended ear.

Analysis of the percentages of correct responses

The mean percentage of correct responses and the standard deviations for 11 patients, as well as for 11 normal controls, for each session, are shown in Table 7. The mean percentage of correct responses of patients and normal controls are plotted in Fig. 5. Judging from Table 7 and Fig. 5, it appears that patients exhibited a lower percentage of correct responses than normal controls in the DICHOTIC 1 kHz task and that patients exhibited a lower percentage of correct responses when engaged in right-ear tasks as opposed to left-ear tasks. As in the case of the reaction time data, an analysis of variance for the percentage of correct responses was conducted considering the same factors as mentioned above. The analysis of variance results are presented in Table 8. The following factors were found to have had a significant influence ($p < .01$) on the results: individual differences, the required task, and (group category x the required task). The means of the mean percentages of the correct responses of patients and normal controls from Fig. 5 were then obtained and plotted, as shown in Fig. 6. The means, expressed in terms of percent, of the mean percentages of the correct responses of patients and normal controls, respectively, for each task are as follows: MONAURAL, 97.0, 99.8; DICHOTIC 500 Hz, 92.9, 96.6; DICHOTIC 1 kHz, 69.7, 90.9. Judging from Fig. 6, the analysis of variance results indicate the following. 1) Patients exhibited a lower percentage of correct responses than normal controls in the DICHOTIC 1 kHz task. 2) Patients, as well as normal controls, displayed a progressive decrease in their mean percentage of correct responses from MONAURAL to DICHOTIC 500 Hz to DICHOTIC 1 kHz. The analysis of variance results, however, did not indicate that there were

Variables	d.f.	V	Fo
S (group category)	1	1601499	17.47**
e_1 (individual differences)	20	91683	27.72**
B (attended ear)	1	3534	1.07
C (response hand)	1	7594	2.30
D (task)	2	315433	95.35**
B X C	1	787	0.24
B X D	2	8033	2.43
C X D	2	5140	1.55
B X C X D	2	204	0.01
S X B	1	3652	1.10
S X C	1	2304	0.70
S X D	2	24968	7.55**
S X B X C	1	872	0.26
S X B X D	2	1425	0.43
S X C X D	2	1202	0.36
e_2	222	3308	

**p<0.01 *p<0.05

Table 6 *Results of the analysis of variance for the reaction times*

		LE——LH	LE——RH	RE——LH	RE——RH
Normal Control (n=11)	Monaural	100.0 ± 0	99.4 ± 1.3	100.0 ± 0	99.7 ± 1.0
	Dichotic(500Hz)	97.3 ± 5.1	95.0 ± 8.3	98.4 ± 4.2	95.8 ± 8.2
	Dichotic(1kHz)	89.7 ± 12.0	90.7 ± 7.6	92.0 ± 8.8	91.1 ± 12.1
Schizophrenia (n=11)	Monaural	96.1 ± 13.1	93.0 ± 14.5	94.6 ± 9.1	95.0 ± 14.5
	Dichotic(500Hz)	94.4 ± 10.5	95.7 ± 6.9	90.4 ± 14.1	91.0 ± 9.0
	Dichotic(1kHz)	72.9 ± 22.6	77.4 ± 22.5	64.8 ± 27.6	63.5 ± 29.0

Table 7 *Mean correct percentages for each task for schizophrenics and normal controls*

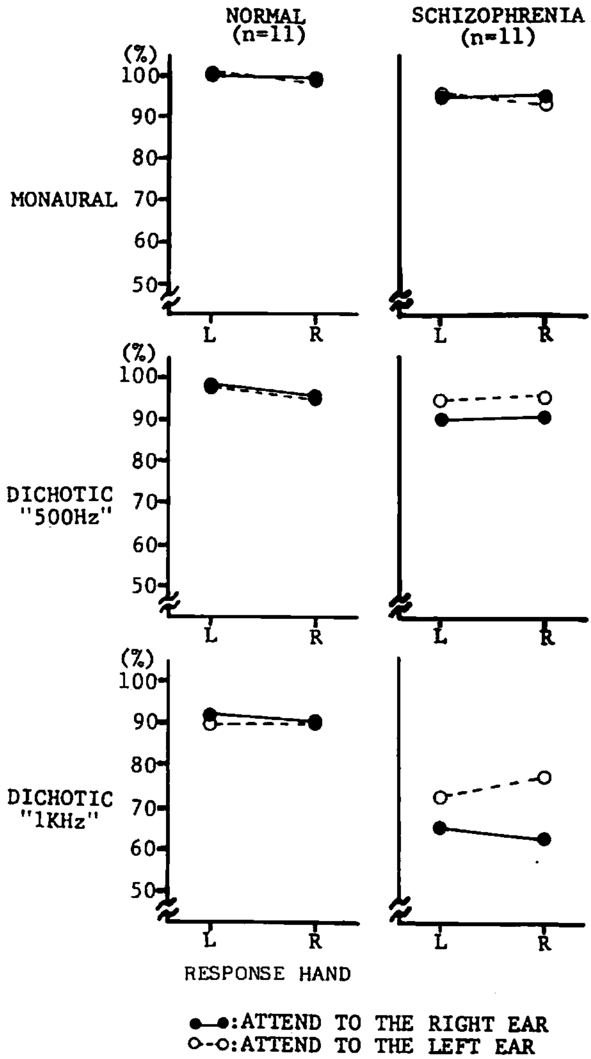

Fig. 5 *Mean correct percentages for each task for schizophrenics and normal controls*

Variables	d.f.	V	Fo
S (group category)	1	5654	5.23*
e_1 (individual differences)	20	1081	7.60**
B (attended ear)	1	121	0.85
C (response hand)	1	91	0.64
D (task)	2	8086	56.86**
B X C	1	72	0.51
B X D	2	298	2.10
C X D	2	15	0.11
B X C X D	2	87	0.61
S X B	1	311	2.19
S X C	1	49	0.34
S X D	2	2364	16.62**
S X B X C	1	1	0.01
S X B X D	2	405	2.85
S X C X D	2	11	0.08
e_2	222	142.2	

$^{**}p<0.01$ $^{*}p<0.05$

Table 8 *Results of the analysis of variance for the percentages of correct responses* any differences in the percentage of correct responses concerning the sidedness of the attended ear. In the next step, the data concerning exclusively the DICHOTIC 1 kHz task was employed in the analysis of variance, since there appeared to be remarkable differences concerning the sidedness of the attended ear in this particular task as opposed to the others among the patients (Fig. 5). In this analysis of variance, the following factors were considered: 1) group category; 2) individual differences; 3) sidedness of the attended ear; and 4) sidedness of the response hand. The analysis of variance results are presented in Table 9. The following factors were found to have had a significant influence ($p < .01$) on the results: group category, individual differences, and (group category x sidedness of the attended ear). The means of the mean percentages of the correct responses of patients and normal controls, concerning exclusively the DICHOTIC 1 kHz task from Fig. 5, were then obtained and plotted, as shown in Fig. 7. The means, expressed in terms of percent, of the mean percentages of the correct responses of schizophrenics, as well as of normal controls respectively, are as follows: left-ear task, 75.2, 90.2; right-ear task, 64.1, 91.5. The analysis of variance results indicate that patients exhibited a significantly lower percentage of correct responses than normal controls when engaged in the DICHOTIC 1 kHz task, ($p < .01$); and that in this particular task patients displayed a significantly lower percentage of correct responses when utilizing the right ear, as compared to the left, ($p < .01$). The analysis of variance of the percentages of correct responses concerning exclusively the DICHOTIC 500 Hz task, in patients as well as normal controls, indicated that there were no significant differences concerning the sidedness of the attended ear.

Discussion

In this experiment, non-verbal sounds were employed as stimuli instead of verbal sounds, since it has been found that verbal sounds are processed specifically in the dominant hemisphere, thus making them unsuitable for this experiment. However, discussion concerning the differences in the ability of both ears (hence, of both hemispheres) in processing such sounds as were employed in this experiment is necessary. As mentioned previously, the analysis of the data obtained in this experiment indicated that there were no significant differences concerning the sidedness of the attended ear in the case of normal controls. Some authors have previously reported results concerning right- and left-ear differences in processing sounds such as those as employed in this experiment. These sounds are usually designated "chirps" or "pitch contours". Darwin (1969) conducted a dichotic listening test in which pitch contours, superimposed on non-verbal sounds, were presented dichotically, resulting in the left ear displaying a superiority in processing. Blechner (1976) presented chirps to one ear, while simultaneously presenting "white noise" to the other. In this experiment, subjects were required to detect one target chirp from among various chirp sounds. Blechner reported that left-ear tasks produced shorter reaction times, but there were no differences in the percentage of correct responses between the right ear and the left ear. The method employed in this experiment was similar to that used in Blechner's study. Tsunoda (Note 1) reported results concerning right- and left-ear differences in processing frequency-

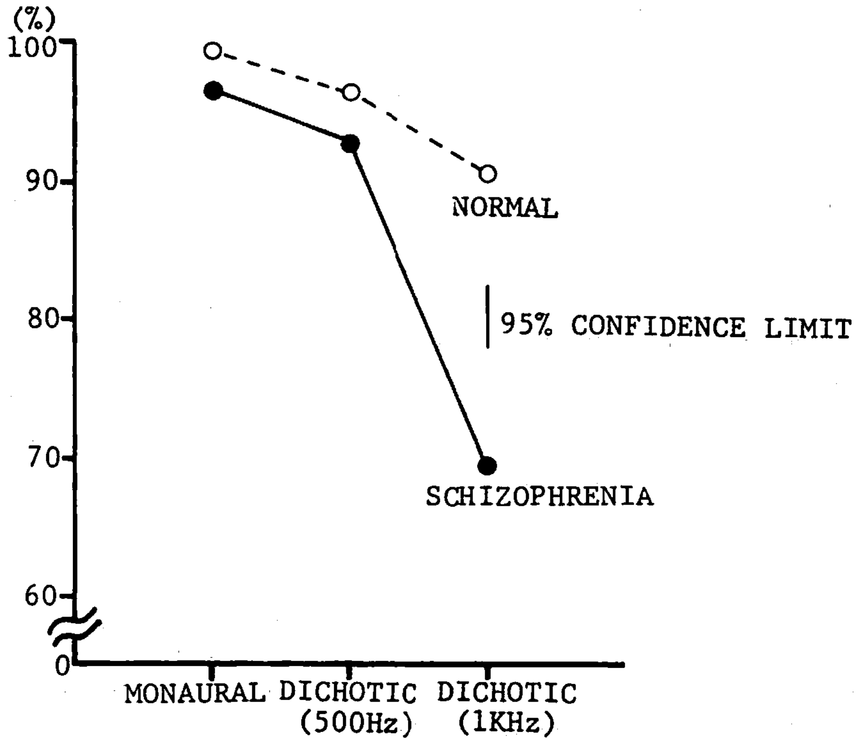

Fig. 6 *Mean correct percentages for each task for schizophrenics and normal controls. In this figure, the data for both ears and both hands are combined.*

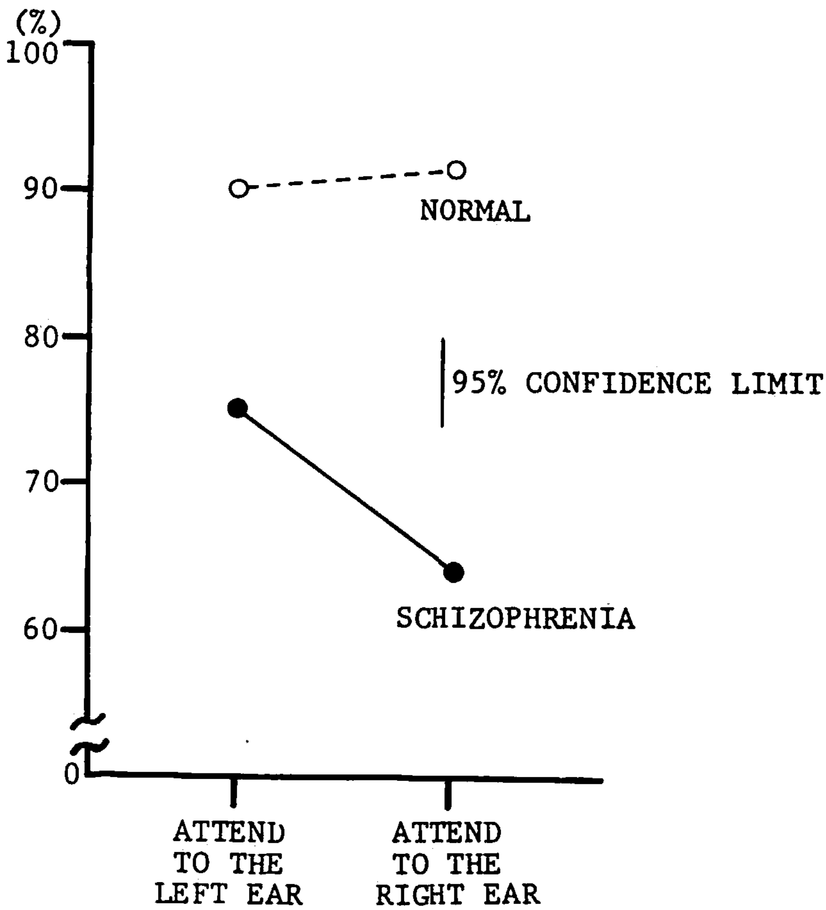

Fig. 7 *Mean correct percentages for the DICHOTIC 1 kHz task for schizophrenics and normal controls. In this figure, the data for both hands are combined.*

Variables	d.f.	V	Fo
S (group category)	1	9900	8.12**
e_1 (individual differences)	20	1219	12.11**
B (attended ear)	1	517	5.13*
C (response hand)	1	80	0.79
S X B	1	843	8.37**
S X C	1	22	0.22
B X C	1	14	0.14
S X B X C	1	12	0.12
e_2	60	100.7	

**p<0.01 *p<0.05

Table 9 *Results of the analysis of variance for the percentages of correct responses in the DICHOTIC 1 kHz task* modulated sounds utilizing his own method. Six Japanese served as subjects in his experiment. According to his results, four out of the six displayed a left ear superiority, while the other two displayed a right ear superiority. Many previous authors have reported results indicating left ear superiority in processing chirps; however, others have reported results inconsistent with these. For example, in Blechner's results, there were no differences in the percentages of correct responses between right- and left-ear tasks, while in Tsunoda's results, two out of the six participants displayed a right ear superiority. Hence, tasks employing frequency-modulated sounds do not seem to produce consistent results, as opposed to tasks involving verbal sounds. Factors which may have had some influence on the results obtained in this study are as follows. 1) The stimuli and methods employed deviated somewhat from those employed by Darwin and Blechner. 2) The processing strategies could have differed from session to session, or they could have varied within sessions, thus producing varied results concerning right- and left-ear differences. Hence, it is felt by the present authors that further investigation is needed to determine what factors contribute to the inconsistency of the results reported here. However, the result that there were no significant difference in the percentages of correct responses and reaction times concerning sidedness of the attended ear leads to the conclusion that the methods employed in this experiment were suitable for the purpose of this study.

A non-verbal method for responding (key pressing), also, was employed in this experiment so as to avoid the activation of one particular hemisphere.

The target stimuli of the 500 Hz pair produced shorter reaction times and higher percentages of correct responses than those of the 1 kHz pair in schizophrenics, as well as in normal controls (Figs. 4 and 6). The DICHOTIC 1 kHz task produced a sharper decrease in the percentage of correct responses as compared to the decrease produced in the DICHOTIC 500 Hz task, this decrease being more pronounced in patients than in normal controls (Fig. 6). From these results, it may be inferred that the DICHOTIC 500 Hz task was easier to perform than the DICHOTIC 1 kHz task. Factors which may have had some influence on the performance level of the detection tasks are as follows:

1) Even when the output voltage intensity from the audio preamplifier to the headphones remained constant, there appears to have been differences in the loudness-level (phon), and subsequently psychological loudness (sone) according to the physical frequency of the sounds. In this experiment, frequency modulated sounds introduced in the first 50 msec duration of the stimuli served as clues for the differentiation of the stimuli. Although the output voltage intensity remained constant, there may have been a difference in the loudness-level from the point of the introduction of the frequency modulated sounds to the point of the attainment of a frequency plateau state. According to the same loudness-level curve devised by Fletcher & Munson (1953), sounds in the 500 Hz to 2 kHz frequency range with intensities of 40 dB to 80 dB have higher loudness-levels than sounds with a frequency of less than 500 Hz with the same intensity. Judging from this same loudness-level curve, the target stimuli of the 500 Hz pair (250 Hz to 500 Hz), may have showed an increase in loudness-level due to frequency modulation, while the other stimuli showed no significant difference in loudness-level due to frequency modulation. It has been found that the level of psychological loudness increases

exponentially according to the increase in the loudness-level. As shown in the data obtained by Scharf (1978) concerning the relationship between loudness-level and psychological loudness, the target stimuli of the 500 Hz pair, exclusively, displayed a double increase in psychological loudness due to frequency modulation. This finding seems to lead to an explanation of why the DICHOTIC 500 Hz task appeared to be easier to perform than the DICHOTIC 1 kHz task.

2) The effect of inter-ear masking must also be considered. The effect of inter-ear masking created by bone conduction is negligible when compared to the effect of central masking, because of its lower intensity levels. Scherrick and Mangabeira-Albernaz (1961) reported that short and unstationary sounds are masked centrally by sounds of a similar frequency, with a resulting intensity reduction of 10 dB or greater. In this experiment, four combinations of stimuli were presented to the participants, among which only the combination of the target stimuli of the 1 kHz pair and the non-target stimuli of the 500 Hz pair included two FM sounds with similar frequency ranges. According to Sherrick and Mangabeira-Albernaz, the target stimuli of the 1 kHz pair would seem to have been easily masked centrally by the non-target stimuli of the 500 Hz pair. This finding seems to lead to an explanation of why the DICHOTIC 1 kHz task appeared to be more difficult to perform than the DICHOTIC 500 Hz task.

As shown in Fig. 6, patients displayed a far lower percentage of correct responses in the DICHOTIC 1 kHz task in comparison to normal controls. Based upon the results of previous reaction time studies, schizophrenics have been found to display some disturbances in the function of selective attention. Payne & Caird (1967) conducted an experiment in which the reaction times of schizophrenics were measured under distracting conditions, with the result indicating that schizophrenics displayed stronger distractability than normal controls. From this study, they proposed, the hypothesis of disturbed selective attention. Lawson, McGhie & Chapman (1967) also reported that schizophrenics, in performing auditory information processing tasks, were more easily distracted by auditory or visual noises in comparison to normal controls. During the DICHOTIC 1 kHz task of our experiment, the stimuli presented to the non-attended ear distracted all the participants profoundly, with a patients demonstrating a significantly lower percentage of correct responses as compared to normal controls. These results can be interpreted as follows; schizophrenics displayed a disturbance in selective attention functioning, or, strong distractability; hence, they exhibited significantly lower performance levels when engaged in the same tasks in which normal controls displayed low performance levels.

In addition, the following factors may have had some influence on the fact that schizophrenics displayed lower performance levels in all of the tasks (MONAURAL, DICHOTIC 500 Hz, DICHOTIC 1 kHz) as compared to normal controls.

1) Patients were distracted as a result of their internal psychiatric symptoms.

2) Patients were poorly motivated in this experiment.

3) The psychotropic drugs which were given to patients lowered their sensitivity, hence, their ability to perform these vigilance tasks as Loeb, Hawkes, Evans & Alluisi (1965) have previously demonstrated.

These 3 factors, however, cannot be used to interpret the particular decrease in the percentages of the correct responses of patients in the DICHOTIC 1 kHz task.

The DICHOTIC 1 kHz task exclusively produced right- and left-ear differences in patients and at the same time, produced significantly lower performance levels in patients than the other 2 tasks (MONAURAL, DICHOTIC 500 Hz). Schizophrenics displayed a lower percentage of correct responses when engaged in right-ear DICHOTIC 1 kHz tasks than in left-ear DICHOTIC 1 kHz tasks. As previously mentioned, the significantly lower performance level of patients in the DICHOTIC 1 kHz task can be attributed to their high distractability. Ear differences in their performance level can be correlated with this distractability, as reflected in the differences in the two hemispheres. In other words, the left hemisphere may have displayed a higher distractability than the right. Some previous authors have reported results concerning right- and left-ear differences in auditory detection tasks in schizophrenics. Bazhin, Wasserman & Tonkonogii (1975) reported that schizophrenics with auditory hallucinations, as opposed to schizophrenics without auditory hallucinations, and normal controls, demonstrated right- and left-ear differences in the detection of monaurally-presented tone bursts of less than 10 msec duration, and also demonstrated a superiority in left-ear tasks as compared to right-ear tasks. Gruzelier & Hammond (1976) reported that schizophrenics displayed more omission errors when engaged in right-ear tasks for the differentiation of monaurally-presented tone bursts with varied duration than in the left-ear tasks, and that this ear difference decreased as psychotic symptoms were alleviated through the administration of tranquilizing drugs. Colburn & Lishman (1979) reported that schizophrenics, as opposed to normal controls, displayed no REA (right ear advantage) in a dichotic listening test, employing words as stimuli. This study is in agreement with all of the previously mentioned studies concerning the finding that schizophrenics have difficulties in processing auditory stimuli presented to the right ear. In other words, they exhibit processing difficulties in the left hemisphere.

Furthermore, schizophrenics have been reported to demonstrate poorer performance levels in processing stimuli of modalities other than auditory, i.e., visual and tactile, when selectively utilizing the left hemisphere as opposed to the right (Beaumont & Dimond, 1973; Carr, 1980; Green, 1979; Gur, 1978; Weller & Kugler, 1979).

The finding that the left hemisphere of schizophrenics demonstrates a disturbance in the sensory processing system, regardless of sensory modality, seems naturally to lead to the conclusion that these disturbances may arise from some basic and universal mechanisms in the sensory processing system. Therefore, it seems appropriate to suggest that the high distractability of schizophrenics, especially in their left hemisphere, bears responsibility for the production of results such as those obtained in this study.

Previous studies have reported that schizophrenics display slower reaction times as compared to normal controls. This study also revealed that patients demonstrate slower reaction times than normal controls by an average of 150 msec, as shown in Fig. 4. Furthermore, it is interesting to note that there were differences in the reaction time patterns for the different tasks between patients and normal controls. As was previously mentioned, normal controls displayed a greater difference in reaction times between the MONAURAL and DICHOTIC 500 Hz tasks than between the DICHOTIC 500 Hz and DICHOTIC 1 kHz tasks. The patients demonstrated an essentially equal difference between these respective tasks (MONAURAL and DICHOTIC 500 Hz, DICHOTIC 500 Hz and DICHOTIC 1 kHz). Furthermore, comparing the MONAURAL and DICHOTIC 500 Hz tasks, normal controls displayed a greater difference in reaction times than patients; however, comparing the DICHOTIC 500 Hz and DICHOTIC 1 kHz tasks, there seemed to be no significant difference in reaction times between patients and normal controls. It is noteworthy that the reaction time difference between patients and normal controls was greater in the MONAURAL task than in the DICHOTIC 1 kHz task; with the latter task producing the greatest difference in the percentage of correct responses between schizophrenics and normal controls.

Venables (1958) and Wishner et al. (1978) conducted research on the varying patterns of choice reaction times as related to the complexity of the stimulus. Contrary to their expectations, they found that there were no significant differences between schizophrenics and normal controls in the varying patterns of reaction times. The results of Venables and Wishner et al., as well as those of the present paper, lead to Yates' hypothesis (Yates, 1966): namely, schizophrenics are basically slower than normal controls in processing sensory information. The result obtained in this study of a reaction time difference between schizophrenics and normal controls was greatest in the MONAURAL task, this task being the least complex of the three tasks, leads to Steffy's "redundancy-associated deficit model of schizophrenics" (Bellisimo & Steffy, 1973).

It was mentioned previously that schizophrenics seem to display a higher distractability when engaged in sensory information processing utilizing the left hemisphere, as compared to the right. At this point, the genesis of the results mentioned above will be discussed with special reference to the relationship between the attention mechanism and the integration mechanism for the two hemispheres.

Dimond & Beaumont (1973) suggested that there are two vigilance systems involved in visual information processing; one in each hemisphere. The vigilance system in the left hemisphere initially attains a high performance level, however, a decline in this performance level can be observed soon afterwards. While the vigilance system in the right hemisphere works initially at a lower level than that of the left, it, however, maintains a constant performance level. Dimond (1976) conducted an experiment in which split-brain patients were required to perform vigilance tasks employing tachistoscopically-presented stimuli. The results of this study indicated that the left hemisphere displayed a greater number of non-response periods (gaps) than the right hemisphere. An increase in the time period of the experimental session resulted in an increase in the number of gaps of more than 15 seconds duration in the left hemisphere. The characteristics of these gaps have not yet been clearly defined; however, these gaps may be correlated with the distractability of the left hemisphere. Heilman & Van Den Abell (1979, 1980) combined psychological tests and EEG examinations to investigate the issue concerning which hemisphere plays a dominant role in increasing the level of attention. They concluded that the right hemisphere plays a more significant role in this process.

If the above mentioned results are correct, it can be suggested that the attention mechanism has a dual system, as Dimond (1976) has proposed, which is correlated with cerebral lateralization, and that under usual conditions, these system work in tandem.

Ellenberg & Sperry (1979, 1980) conducted experiments employing normal controls, totally split-brain patients and partially split-brain patients to check the results of Dimond & Beaumont (1973) and Dimond (1976). In these experiments, the subjects were required to perform various tasks using both hands, independently. They found that normal controls and totally split-brain patients displayed essentially equal performance levels; however, the partially split-brain patients displayed a lower performance level than the other two groups. Although they could not reproduce the results of Dimond & Beaumont (1973) and Dimond (1976), they concluded that the integration mechanism plays an important role in attention.

Judging from the results of the above mentioned studies, the following can be proposed.

If these two conditions can be met, it may be the case that schizophrenics demonstrate lower performance levels when engaged in psychological tasks utilizing the left hemisphere.

Condition 1) There is a difference in characteristics of the vigilance systems of each hemisphere, as Dimond, et al. have suggested.

Condition 2) Schizophrenics demonstrate disturbances in the integration of both hemispheres.

Previous studies concerning cerebral lateralized functioning in schizophrenics have drawn two different conclusions: 1) Schizophrenics demonstrate left hemispheric dysfunction. 2) Schizophrenics demonstrate integration disturbances in both hemispheres. However, the present authors' hypothesis proposes a unification of these two conclusions. But this hypothesis is purely speculative. Further investigation is needed concerning the following issues; 1) the relationship between the attention mechanisms and the integration mechanisms of both hemispheres in normal subjects; and 2) the differences in the characteristics of the attentional disturbances between schizophrenics and split-brain patients.

Testing this hypothesis will help clarify the psychopathological symptoms of schizophrenics in neurological terms and add to the development of the knowledge of the pathogenesis and therapeutics of schizophrenia. In this sense, the authors feel it is necessary that future research should be conducted in the direction of clarifying the nature of the attentional deficit in schizophrenics in neuropsychological terms.

Acknowledgments

We would like to thank Dr. Y. Saitoh, Department of Neuropsychiatry, University of Tokyo, and Mr. Y. Takahashi, Nippon Roche Co., Ltd., for their assistance in the analysis of the data. We would also like to thank Mr. K. Yamazaki, Miss M. Iwama and Miss A. Fukuyasu for their assistance in conducting this experiment.

This study was supported in part by a Grant-in-Aid (No. 557268) from the Japanese Ministry of Education, Science and Culture.

Note

1. Tsunoda, T. Nihonjin no Noh. In Japanese. Tokyo: Taishukan-Shoten, 1978.

References

Bazhin, E.F., L.I. Wasserman and I.M. Tonkonogii. Auditory hallucinations and temporal lobe pathology. Neuropsychologia, 1975, 13, 481-487.

Beaumont, J.G. and S.J. Dimond. Brain disconnection and schizophrenia: British Journal of Psychiatry, 1973, 123, 661-662.

Bellissimo, A. and R.A. Steffy. Redundancy-associated deficit in schizophrenic reaction time performance. Journal of Abnormal Psychology, 1972, 80, 299-307.

Blechner, M.J. Left-ear advantage for sounds characterized by a rapidly varying resonance frequency. HASKINS LABORATORIES: Status Report on Speech Research, 1976, SR-48, 279-286.

Carr, S.A. Interhemispheric transfer of stereognostic information in chronic schizophrenics. British Journal of Psychiatry, 1980, 136, 53-58.

Colburn, C.J. and W.A. Lishman. Lateralization of function and psychotic illness: A left hemisphere deficit? In J. Gruzelier and P. Flor-Henry (Eds.), Hemisphere Asymmetries of Function in Psychopathology. Amsterdam: Elsevier/North-Holland, 1979.

Darwin, C.J. Ear differences and hemispheric specialization. In B. Milner (Ed.), Hemispheric Specialization and Interaction. Cambridge: MIT Press, 1969.

Dimond, S.J. and J.G. Beaumont. Difference in the vigilance performance of the right and left hemispheres. Cortex, 1973, 9, 256-265.

Dimond, S.J. Depletion of attentional capacity after total commissurotomy in man. Brain, 1976, 99, 347-356.

Ellenberg, L. and R.W. Sperry. Capacity for holding sustained attention following commissurotomy. Cortex, 1979, 15, 421-438.

Ellenberg, L. and R.W. Sperry. Lateralized division of attention in the commissurotomized and intact brain. Neuropsychologia, 1980, 18, 411-418.

Fletcher, H. and W.A. Munson. Speech and Hearing in Communication. New York: D. Van Nostrand, 1953.

Geschwind, N. Disconnection syndromes in animals and man I, II. Brain, 1965, 88, 237-294, 585-644.

Green, P. Defective interhemispheric transfer in schizophrenia. Journal of Abnormal Psychology, 1978, 87, 472-480.

Gruzelier, J. and N. Hammond. Schizophrenia: A dominant temporal-limbic disorder. Research Communication in Psychology, Psychiatry and Behavior, 1976, 1, 33-72.

Gur, R.E. Left hemisphere dysfunction and left hemisphere overactivation in schizophrenia. Journal of Abnormal Psychology, 1978, 87, 226-238.

Heilman, K.M. and T. Van Den Abell. Right hemisphere dominance for mediating cerebral activation. Neuropsychologia, 1979, 17, 315-321.

Heilman, K.M. and T. Van Den Abell. Right hemisphere dominance for attention: The mechanism underlying hemispheric asymmetries of inattention (neglect). Neurology, 1980, 30, 327-330.

Kimura, D. Cerebral dominance and the perception of verbal stimuli. Canadian Journal of Psychology, 1961, 15, 166-171.

Kinsbourne, M. The mechanism of hemispheric control of the lateral gradient of attention. In P.M.A. Rabbit and S. Dornic (Eds.), Attention and performance V. New York: Academic Press, 1975.

Lawson, J.S., A. McGhie and J. Chapman. Distractability in schizophrenic and organic cerebral disease. British Journal of Psychiatry, 1967, 113, 527-535.

Lerner, J., I. Nachson and A. Carmon. Responses of paranoid and nonparanoid schizophrenics in a dichotic listening task. Journal of Nervous and Mental Disease, 1977, 164, 247-252.

Loeb, M., G.R. Hawkes, W.O. Evans and E.A. Alluisi. The influence of d-amphetamine, benactyzine, and chlorpromazine on performance in an auditory vigilance task. Psychonomic Science, 1965, 3, 29-30.

McGhie, A., J. Chapman and J.S. Lawson. The effect of distraction on schizophrenic performance. British Journal of Psychiatry, 1965, 111, 391-398.

Payne, R.W. and W.K. Caird. Reactive time, distractability and overinclusive thinking in psychotics. Journal of Abnormal Psychology, 1967, 72, 112-121.

Scharf, B. Loudness. In E.C. Carterette and M.T. Friedman (Eds.), Handbook of Perception. New York: Academic Press, 1978.

Shakow, D. Segmental set: A theory of the formal psychological deficit in schizophrenia. Archives of General Psychiatry, 1962, 6, 1-17.

Sherrick, C.E. Jr. and P.L. Mangabeira-Albernaz. Auditory threshold shifts produced by simultaneously pulsed contralateral stimuli. Journal of Acoustical Society of America, 1961, 33, 1381-1385.

Sperry, R.W. Mental unity following surgical disconnection of the cerebral hemispheres. Harvey Lecture Series, 1968, 62, 293-323.

Springer, S.P. Ear asymmetry in a dichotic detection task. Perception and Psychophysics, 1971, 10, 239-241.

Sternberg, S. The discovery of processing stages: Extensions of Donder's method. Acta Psychologica, 1969, 30, 276-315.

Trevarthen, C. Double visual learning in split-brain monkeys. Science, 1962, 136, 258.

Venables, P.H. Stimulus complexity as a determinant of the reaction time of schizophrenics. Canadian Journal of Psychology, 1958, 12, 187-190.

Weller, M. and B.T. Kugler. Tactile discrimination in schizophrenic and affective psychoses. In J. Gruzelier and P. Flor-Henry (Eds.), Hemisphere Asymmetries of Function in Psychopathology. Amsterdam: Elsevier/North-Holland, 1979.

Wishner, J., M.K. Stein and A.L. Peastrel. Stages of processing in schizophrenia: Sternberg's paradigm. In L.C. Wynne, R.L. Cromwell and S. Matthysse (Eds.), The Nature of Schizophrenia. New York: John Willey & Sons Inc., 1978.

Yates, A.J. Psychological deficit. In P.R. Farnworth (Ed.), Annual Review of Psychology (1966). Palo Alto: Annual Reviews Inc., 1966.