Schizophrenia: A Neurophysiological Evaluation of Abnormal Information Processing

Abstract. *Evoked potential indices of an early and late stage of attentional processing were recorded from schizophrenic and normal subjects during dichotic listening tasks. Despite slow and inaccurate detections, the schizophrenic subjects were able to focus selectively to different ears but only at a fast stimulation rate, showing integrity of the early selective stage. They showed an abnormal late stage, indicating inefficiency in processing information from detected targets. Marked deficits at a slow stimulation rate and during divided attention suggest that the schizophrenic attention disorder is one of control and maintenance of a selective processing strategy rather than of general slowness or absence of selectivity.*

Impairment of selective attention is an important aspect of the schizophrenic thought disorder. Electrophysiological studies have reported a general attenuation of evoked potentials in schizophrenics in diverse perceptual tasks. It is not clear how this amplitude attenuation can be explained by the attentional deficit (*1*). Broadbent has differentiated two levels of attentional selectivity: stimulus set—selecting a channel of information characterized by some simple physical attribute—and response set—selecting those stimuli requiring a particular response (*2*). Within this framework the schizophrenic attentional disorder could be due to either a stimulus-set or a response-set deficiency (*3*) to a general slowness of processing that is unable to keep up with the demands for stimulus-response association (*4*), or to a disorder in the control mechanisms that create and maintain the strategy of selective information processing (*5*). Behavioral measures have not clearly demonstrated any of these theories (*3*). In this study, neurophysiological results disconfirm the first three theories and support the hypothesis of disordered control mechanisms in schizophrenia.

Two evoked potentials (N1 and P3) reflect stimulus set and response set, respectively, in dichotic listening tasks in which the subject has to focus his attention and detect occasional targets among standard tones in one ear and ignore all tones presented to the other ear (*6*). The N1 potential (latency, 100 to 150 msec) is larger for all tones in the attended ear, and P3 (latency, 300 to 600 msec) is larger only for the detected targets. The relative amplitude difference between the responses to attended and ignored tones provides the measure of selective focusing on one auditory channel (stimulus set) and between the attended standard tones and targets, the measure of response-set selection. In a similar procedure, we recorded the auditory evoked potentials of schizophrenic subjects, adding a "divided" attention task where subjects had to attend and detect all targets in both ears. Each focused and divided attention task was run at fast (250 to 750 msec) and slow (500 to 1500 msec) randomized intervals of stimulation. Task order was counterbalanced within and across subjects. Tones with a duration of 15 msec, a rise-fall time of 5 msec, an intensity of 65 dB peak sound pressure level (45-dB normal hearing level) were presented dichotically through earphones. The "standard" pitch in the left ear was 1000 Hz and in the right ear 2000 Hz. A random 10 percent of the tones were targets with a frequency of 1450 Hz regardless of the ear stimulated. Subjects pressed a button in response to targets in the task-relevant ear. Detection accuracy was measured as the percentage of correct responses within 200 and 1000 msec after the target was presented (*7*).

Schizophrenic ($N = 20$) and normal subjects ($N = 20$) were selected according to research diagnostic criteria (*8*) and were group-matched for age (27 years), sex (36 males and 4 females), and educational background (respectively, 13.8 and 15.1 school years). On the Bannister-Fransella test for thought disorders (*9*), all patients scored above the 95th percentile relative to a normative group of psychotics without thought disorders.

Evoked potentials from Fz, Cz, and Pz electrodes (right mastoid reference) and vertical electro-oculograms were recorded on frequency modulation tape and averaged off-line with sweep durations of 250 and 900 msec (*10*). The N1 amplitude was measured at 125 msec at Cz on the 250-msec sweep, and P3 amplitude on the 900-msec sweep at the maximum positivity between 250 and 900 msec at Pz. Reaction time, detection accuracy, and N1 and P3 amplitudes are summarized in Table 1. They were analyzed by three-way analyses of variance (subject group by stimulus rate by attention instruction) for repeated measures. Significant ($P < .01$) main effects and interactions were further analyzed by the Scheffé procedure (*11*). Since all schizophrenics were being treated with phenothiazines, a preliminary analysis of variance within the schizophrenic sample was performed between those treated with high and low dosage, subdividing the two subgroups at the midpoint of the dosage scale. There was no significant difference between the two subgroups on P3, reaction time, and detection accuracy, except for N1 amplitude. Thus, dosage does not affect any measures except N1 (*12*). The only way to assess schizophrenic abnormalities relative to normal responses, while taking into account the difference in medication between the two groups, was to include all subjects of both groups into one single analysis of covariance, thereby subtracting the variance due to medication levels (*13*).

The schizophrenics performed the tasks more slowly and less accurately than the controls. Stimulus rate affected reaction time in all subjects: average reaction times at fast and slow stimulus rates were 449 and 498 msec for the controls and 536 and 586 msec for the schizophrenics. Analyses of detection accuracy showed significant effects of subject group and attention instruction, no effect of stimulus rate, and a significant interaction between subject group and attention instruction. This interaction occurred because the schizophrenics performed particularly poorly during divided attention (57 percent) relative to focused attention (82 percent), while the normals performed equally well (90 to 94 percent) in both tasks.

The N1 potential was significantly larger for the controls than for the schizophrenics, for the slow than for the fast rate of stimulation, and for the attended than for the ignored stimuli (Fig. 1). The interaction effect between groups, attention instruction, and rate was a result of the schizophrenics' showing no effect of focused and divided attention at the slow rate, no effect of divided attention at the fast rate, and a significant effect of focused attention at the fast rate. The analysis of covariance removed the absolute amplitude difference between subject groups, leaving significant the effects of attention instruction and stimulus rate, and therefore showing that in the schizophrenics, N1 amplitude was significantly modulated by attention only at the fast stimulation rate independently of drug dosage (*14*). These results demonstrate that schizophrenics are able to focus selectively to different channels of auditory stimuli.

Despite this selectivity of stimulus set, the schizophrenics still performed poorly on the target-detection task. The per-

Table 1. Mean amplitude (± standard deviations) of evoked potentials and performance measures for all attention conditions at fast and slow rates of stimulation for the normal and schizophrenic groups.

Group	Evoked potentials (μV)						Correct (%)		Reaction time (msec)	
	N1			P3						
	Focused	Divided attention	Inattention	Focused	Divided attention	Inattention	Focused	Divided attention	Focused	Divided attention
					Normal					
Fast	−2.7 ± 1.5	−2.5 ± 1.5	−1.7 ± 1.3	7.1 ± 4.4	5.5 ± 4.1	2.9 ± 2.2	93.4 ± 6.1	90.1 ± 7.2	456.5 ± 93.3	441.2 ± 73.4
Slow	−4.0 ± 1.8	−4.9 ± 2.7	−2.7 ± 1.7	8.3 ± 4.5	6.1 ± 3.6	3.1 ± 2.3	95.3 ± 4.0	91.4 ± 6.3	487.8 ± 78.9	508.0 ± 72.4
					Schizophrenic					
Fast	−2.0 ± 1.5	−1.7 ± 1.6	−1.2 ± 1.2	5.4 ± 3.1	3.2 ± 2.2	2.1 ± 1.8	81.9 ± 17.4	56.1 ± 12.8	519.2 ± 95.1	552.6 ± 99.9
Slow	−2.3 ± 1.9	−2.3 ± 1.7	−2.2 ± 1.5	5.8 ± 3.4	3.5 ± 2.3	2.1 ± 1.9	74.5 ± 20.6	58.7 ± 25.0	585.0 ± 90.3	586.1 ± 98.7

formance deficit in schizophrenia thus occurred independently of N1 and of any disturbance of the selectivity of stimulus-set attention. However, part of the cognitive deficit may result in an abnormality in organizing or maintaining the processes of stimulus-set selection. According to Broadbent's stimulus-set model (*2*), this pattern of results indicates that schizophrenics have difficulty in broadening the scope of stimulus-set selection during divided attention and in sustaining channel selectivity at slower rates of stimulus presentation (*15*).

The P3 amplitude was significantly larger for the normal subjects than for the schizophrenics, for slow than for fast stimulus rates, for the attended than for the ignored targets, and for focused than for divided attention (Fig. 1) (*16*). Part of the difference in amplitude between groups may have been related to their different detection performances. The schizophrenics missed significantly more detections and had significantly longer and more variable reaction times. We therefore decided to examine the evoked potentials when the behavioral response was both accurate and rapid—between 200 and 500 msec. The effects were essentially the same. The schizophrenics had a significantly smaller P3 ($\bar{X}$ = −4.5 ± 3.3) than normal subjects ($\bar{X}$ = −7.7 ± 3.7) throughout the experimental manipulations (*17*). This difference also persisted in the analysis of covariance and was thus not related to medication (*14*). The P3 amplitude at reaction times longer than 500 msec was smaller for the schizophrenics, but this difference was not significant.

The results demonstrate a general schizophrenic abnormality of the cerebral processes underlying the P3 component of the evoked potential. A similar reduction in P3 amplitude has been reported in schizophrenics in other studies in which attention effects on N1 were not assessed (*1*). Our experiment indicates that the P3 abnormality is not secondary to any lack of stimulus-set attention or motivation on the part of the schizophrenics since it occurs when they are selectively attending the stimuli of the relevant ear (as demonstrated by N1 modulation between conditions). In information theory, P3 amplitude has been related to the amount of unequivocal task-relevant information processed from a signal (*18*). The fact that P3 remained abnormally small even when targets were detected accurately therefore suggests that schizophrenics suffer from a general inefficiency in obtaining information from significant stimuli. This deficit is not related to arousal effects, since the abnormality is no more severe at rapid stimulus rates. Furthermore, the absence of any P3 to the target stimuli in the unattended ear makes it difficult to attribute the cognitive disorder in schizophrenia to response interference (*3*).

This experiment demonstrates that schizophrenics manifest abnormalities of both stimulus-set and response-set attention. Neither of these abnormalities can be due to the other because they occur under different conditions. The stimulus-set abnormality occurs only at slow stimulus rates or under conditions of divided attention (*19*). A response-set abnormality occurs at all times provided the response selection is reasonably rapid. This combination of findings suggests that the schizophrenic subject has difficulty in sustaining channel selectivity at slow rates of stimulus presentation and in adapting such selectivity for divided attention. He or she is unable to organize and maintain an effective strategy for processing information. The slowness and inefficiency of schizophrenic information processing could result from an inability to organize the processes in an optimal manner. This concept of disor-

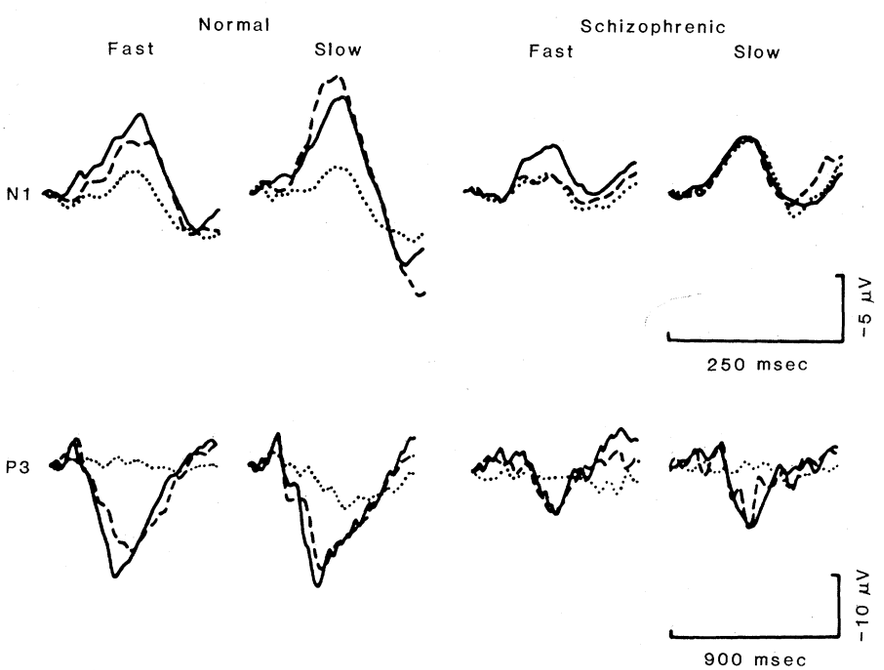

Fig. 1. Evoked potentials for one schizophrenic and one normal subject in the two speed conditions of the dichotic tasks: during focused attention to one ear (solid line), during inattention to the corresponding ear (dotted line), and during divided attention to two ears (dashed line). For N1, tracings were recorded for standard tones at Cz. For P3, recorded at Pz, averaging was restricted to targets to which responses occurred within 200 to 500 msec.

dered control is similar to that originally formulated by Bleuler to describe the disintegration of psychic processes in schizophrenia that renders them "incapable of holding the train of thought in the proper channel" (*20*).

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References and Notes

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2. D. E. Broadbent, *Decision and Stress* (Academic Press, London, 1971).
3. W. E. Broen, *Schizophrenia Research and Theory* (Academic Press, New York, 1968).
4. A. J. Yates, in *Annu. Rev. Psychol.* **17**, 111 (1966).
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6. S. A. Hillyard, R. F. Hink, V. L. Schwent, T. W. Picton, *Science* **182**, 177 (1973).
7. If four consecutive misses or false alarms occurred, recording was interrupted to reinforce the subject for rapid or accurate detections. Rest periods occurred every 4 minutes within and between sessions with a break in the middle. Before the experiment, subjects were practiced at the different experimental rates with the tones presented to only one ear, then to both ears, and then in the divided-attention task, which they all found extremely difficult.
8. R. L. Spitzer, J. Endicott, E. Robins, *Research Diagnostic Criteria (RDC) for a Selected Group of Functional Disorders* (Biometrics Research–New York State Psychiatric Institute, New York, 1975). According to RDC, the diagnosis of six patients was acute schizophrenia. Statistical comparisons showed no difference between acutely and nonacutely ill subjects, except that the former were treated with a higher medication dosage.
9. D. Bannister, *Br. J. Soc. Clin. Psychol.* **14**, 169 (1975).
10. The system bandpass was 0.1 to 300 Hz. The 900-msec sweep did not average responses within 900 msec of the beginning of a previous sweep. Trials contaminated by eye movement or muscle artifact were rejected before being averaged.
11. Details of the analyses of variance and F ratios are available on request. Because of missing values in the patients' group for P3 ($N = 17$) and for behavioral measures ($N = 18$), but not in the normal groups ($N = 20$), we used the least-squares solution for groups of unequal N available in the program BMD P2V [W. J. Dixon and M. B. Brown, *BMDP* (Univ. of California Press, Berkeley, 1977); R. E. Kirk, *Experimental Design* (Brooks & Coles, Belmont, 1968)] and the Scheffé post hoc procedures, which are robust to deviations of analyses of variance postulates [V. Keith, *Design and Analysis in Experimentation* (Univ. of Ottawa Press, Ottawa, 1971)]. For the significant interaction effects, simple main effects were tested according to Kirk, taking unequal N's into account and pooling the different error terms.
12. The N1 amplitude in the low-dosage group (3.57 ± 1.85) was significantly larger than that in the high-dosage group (2.62 ± 1.69) [$F(1, 18) = 10.43$, $P < .005$].
13. The analysis of covariance (BMD P2V) was performed on measures of the 900-msec tracing of the 15 patients being treated uniquely with fluphenazine decanoate and the 20 normal subjects. (Five patients had been treated with an additional phenothiazine, chlorpromazine, in the preceding month.) Dosage was measured as the weekly average per kilogram of body weight [W. Quan and R. J. Carlson, *Ann. R. Coll. Phys. Surg. Can.* **12**, 80 (1979)].
14. Subject-group differences remained significant on all measures except on N1 absolute amplitude. The dosage covariate mean and standard deviation were 9.5 ± 8.1 for the schizophrenic groups and 0 for the normals. For N1, both rate and attention effects were significant [respectively, $F(1, 33) = 37.1$, $P < .001$; $F(2, 66) = 15.2$, $P < .001$). In the fast-rate condition, the normal and schizophrenic covariate adjusted means were, respectively, 5.7 and 5.2 for the focused attention condition, 4.6 and 4.7 for the ignored condition, 5.5 and 4.8 for the divided condition. In the slow-rate condition, they were 8.4 and 6.9 for the focused condition, 6.4 and 6.4 for the ignored condition, and 7.7 and 5.6 for the divided condition. There are other reports of a decreased N1 amplitude with phenothiazine medication [B. Saletu, T. M. Itil, M. Saletu, *Am. J. Psychiatry* **128**, 336 (1971); M. S. Buchsbaum, *Schizophr. Bull.* **3**, 105 (1977)]. It could be argued that our analysis of covariance might have removed a schizophrenia-related N1 amplitude effect confounded with the medication covariate. It does not seem to be the case since the behavioral measures most sensitive to the schizophrenic disorder were not related to dosage, and since dosage was not correlated with the two scores (intensity, $r = .08$; consistency, $r = -.19$) of the thought-disorder test. These data indicate that dosage does not reflect a complete confounding of schizophrenia effects with medication effects and that the medication-related effect on N1 cannot be attributed to severity of the disorder studied in this experiment.
15. Our results for the normal subjects are slightly different from those reported by V. L. Schwent, S. A. Hillyard, and R. Galambos [*Electroencephalogr. Clin. Neurophysiol.* **40**, 604 (1976)]. They showed that the attention-related changes in N1 amplitude decreased at slower stimulation rates as the subject became less forced to exclude one channel from processing. Our procedure differed from theirs in that the signal frequency was the same in both ears. Thus, it was still advantageous to attend selectively to one channel even at the slower rate. R. F. Hink, S. T. Van Voorhis, S. A. Hillyard, and T. S. Smith [*Neuropsychologia* **15**, 597 (1977)] showed that when attention was divided between channels, the N1 amplitude was intermediate between the amplitude of the response to stimuli attended under the focus instructions and that to ignored stimuli. Our results in normal subjects showed that the N1 amplitude in the divided condition was equal to or greater than that in the focus condition. Our subjects reported that the divided-attention task was demanding, and they probably allocated more effort to its stimulus processing. The schizophrenics performed poorly during divided attention and had small N1 amplitudes.
16. The decreased P3 amplitude at the faster rates of stimulus presentation and for the divided-attention task is explainable on the basis of the temporal probability of the detected signal [P. F. Fitzgerald and T. W. Picton, *Can. J. Psychol.* **35**, 188 (1981)].
17. The main effects of subject group, stimulus rate, and attention instruction were all significant at $P < .01$.
18. D. S. Ruchkin and S. Sutton, in *Multidisciplinary Perspectives in Event-Related Brain Potentials Research*, D. Otto, Ed. (Environmental Protection Agency, Washington, D.C., 1978).
19. There is some controversy in the literature as to whether the attention-related N1 modulation represents an enhancement of the N1 component or the superimposition of another slower negative wave peaking at 200 to 250 msec [S. A. Hillyard, *Can. J. Psychol.* **35**, 159 (1981)]. This controversy does not detract from the fact that the N1 modulation indexes the selective processing of attended stimuli and is earlier than and distinct from P3 attention modulation. However, this is why we took control amplitude measures at 50-msec intervals in all conditions to assess the effects of possible slow base-line shifts. Our measures taken at 200 and 250 msec do not demonstrate the "attention-instruction by rate" interactions observed on N1 measures (peak, 125 msec), and therefore disconfirm the role of a slow negative wave. Regarding P3, there was no indication of any effect of an overlapping slower positivity in the two groups. Therefore, our N1 and P3 results do not seem to be due to such base-line shifts.
20. E. P. Bleuler, *Textbook of Psychiatry*, A. A. Brill, Transl. [Dover, New York, 1951 (originally 1924)], p. 337. In our experience, nonschizophrenic psychotic and depressed patients (J. Baribeau-Braun and N. Lesèvre, *Adv. Biol. Psychiatry*, in press) do not show the same P3 abnormalities that we found in schizophrenic patients, and we therefore believe that our results are more descriptive of schizophrenia than of psychosis in general. We have previously proposed [T. W. Picton, K. B. Campbell, J. Baribeau-Braun, G. B. Proulx, in *Attention and Performance*, J. Requin, Ed., (Erlbaum, Hillsdale, N.J., 1978), vol. 7, p. 429] that the frontal lobe may be the location for the cerebral processes controlling both stimulus-set and response-set attention. A frontal lobe disorder would be compatible with findings in cerebral blood flow, neuropsychological, and dopamine studies in schizophrenia.
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Shift Work Among Dual-Earner Couples with Children

Abstract. *In a 1980 sample of U.S. nonfarm households with children and with both spouses employed full time, one-third of the couples included at least one spouse who worked other than a regular day shift. In about one-tenth of the couples the spouses worked entirely different shifts with no overlap in hours. These findings are linked to an earlier study which showed a high prevalence of child care by employed fathers whose wives were employed in certain occupations.*

A decade ago, the employment of women was called "one of America's best-kept national secrets" (*1*). By now it is more widely recognized that women are a major component of the U.S. labor force; as of 1981 they constituted over 43 percent (*2*). The most rapidly growing segment of the labor force is married women. Hence there has been a rise in the prevalence of "dual-earner" families (both spouses employed); by 1981, they made up 52 percent of all married-couple families (with and without children). Couples in which the husband was the only earning spouse constituted 30 percent; in the remaining 18 percent the wife was the only earning spouse or neither spouse was an earner (*2*).

Over half the dual-earner couples have children. An apparently unnoticed phenomenon of these couples is the high prevalence of "shift workers"—individuals who work on other than a regular day shift. In more than one-third of the couples with children in which both spouses work full time, at least one