
Event-Related Potentials in Schizophrenia during Tonal and Phonetic Oddball Tasks: Relations to Diagnostic Subtype, Symptom Features and Verbal Memory

Gerard E. Bruder, Jürgen Kayser, Craig E. Tenke, Michelle Friedman, Dolores Malaspina, and Jack M. Gorman

Background: *This study compares event-related potentials for paranoid patients (n = 13) versus matched undifferentiated patients and unmedicated patients (n = 14) versus matched healthy adults.*

Methods: *Event-related potentials of right-handed patients and control subjects were recorded from 30 electrodes during oddball tasks using consonant–vowel syllables or complex tones. Patients were also assessed using the Positive and Negative Syndrome Scale, the Thought Disorder Index, and the Wechsler Memory Scale.*

Results: *Paranoid patients did not differ from undifferentiated patients in N1 or P3 amplitude but showed larger N2 at frontocentral sites to phonetic stimuli, as well as larger N2 over left than right hemisphere. Unmedicated patients showed reduced N2, but not N1 or P3, compared to control subjects.*

Conclusions: *The N2 findings are consistent with neuropsychological evidence of greater verbal abilities and left hemisphere dominance in paranoid than nonparanoid schizophrenia. The findings also confirm the relationship of P3 to total Brief Psychiatric Rating Scale score, negative symptoms, and verbal associative memory. Biol Psychiatry 2001;50:447–452 © 2001 Society of Biological Psychiatry*

Key Words: Event-related potentials, schizophrenia, paranoid subtype, symptoms, verbal memory

Introduction

A recent study measured event-related potentials (ERPs) from 66 schizophrenic patients during oddball tasks (Kayser et al 2001). The present report takes

advantage of this large sample of well-characterized patients to examine the relation of ERPs in schizophrenia to clinical subtype, symptom severity, verbal memory, and medication status.

The paranoid subtype of schizophrenia is characterized by delusions or hallucinations and absence of flat affect and disorganized speech or behavior, and shows little cognitive impairment (American Psychiatric Association 1994). Seltzer et al (1997) found paranoid patients had better verbal skills, memory for spoken sentences, and problem-solving abilities compared to undifferentiated patients. Paranoid patients might therefore show less reductions of cognitive ERPs, particularly in tasks involving verbal processing. Although two studies did not find differences between paranoid and nonparanoid subtypes in the P3 potential, they relied on an oddball paradigm with tones (Boutros et al 1997; St. Clair et al 1989). The use of both phonetic and tonal tasks enabled us to test the following predictions: 1) paranoid patients will have larger cognitive ERPs than undifferentiated patients, particularly in the phonetic task; and 2) paranoid patients will differ from undifferentiated patients in showing greater N2 over left than right temporoparietal sites in the phonetic task.

We also tested specific predictions concerning the relationship between ERP amplitudes in schizophrenia, clinical severity, and memory function. Based on prior findings, it was predicted that symptom severity will negatively correlate with P3 amplitude (Ford et al 1999; Mathalon et al 2000; Turetsky et al 1998). Greater severity of negative symptoms, and to a lesser extent positive symptoms, will be associated with smaller P3 amplitude (Ford et al 1999). Also, greater Thinking Disturbance on the Brief Psychiatric Rating Scale (BPRS) will correlate with smaller N1 amplitude (Ford et al 1999) and greater thought disorder as measured by the Thought Disorder Index (TDI; Johnston and Holzman 1979), and poorer verbal associative memory will correlate with smaller P3 amplitude (McCarley et al 1993; Nagasawa et al 1999).

From the Department of Psychiatry, Columbia University College of Physicians and Surgeons (GEB, JK, DM, JMG); and the Departments of Biopsychology (GEB, JK, CET, MF), Neurology (DM), and the Lieber Center for Schizophrenia Research (JMG), New York State Psychiatric Institute, New York, New York.

Address reprint requests to Gerard E. Bruder, Ph.D., New York State Psychiatric Institute, Department of Biopsychology, 1051 Riverside Drive, Unit 50, New York, NY 10032.

Received December 5, 2000; revised April 3, 2001; accepted April 11, 2001.

Table 1. Means (and Standard Deviations) for Demographic and Clinical Variables

Variable	Paranoid patients (n = 13, 10 male)		Undifferentiated patients (n = 13, 10 male)		Unmedicated patients (n = 14, 8 male)		Healthy adults (n = 14, 8 male)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (years)	31.0	8.3	32.5	8.4	32.4	9.3	32.9	9.4
Education (years)	13.5	4.2	13.2	2.6	13.4	4.0	14.6	1.9
Onset age (years)	22.1 ^a	5.5	20.4 ^b	5.3	23.4 ^a	8.5		
Illness duration (years)	9.8	7.2	12.6	9.8	11.0 ^a	10.1		
Total BPRS	31.8	5.4	37.6 ^b	10.4	29.9 ^c	7.2		

BPRS, Brief Psychiatric Rating Scale.

^an = 11.

^bn = 12.

^cn = 13.

Methods and Materials

Participants and Assessments

A description of the total sample of 66 patients and diagnostic procedures are given in Kayser et al (2001). Symptom ratings of 60 of these patients were obtained using the Positive and Negative Syndrome Scale (PANSS; Kay et al 1992). Items from the BPRS for computing Total and Thinking Disturbance scores (conceptual disorganization, unusual thought content, hallucinations) were derived from the respective PANSS items. Ratings of formal thought disorder were obtained for 42 patients using the TDI, which was administered and scored by trained raters using the procedures described elsewhere (Johnston and Holzman 1979; Shenton et al 1989; Solovay et al 1986).

We used the data for all 13 patients who met DSM-IV criteria (American Psychiatric Association 1994) for paranoid schizophrenia and selected 13 of 27 undifferentiated patients from the total sample who matched these patients in gender, age, education, and response hand (Table 1). Four paranoid and four undifferentiated patients were unmedicated when tested and are also included when comparing unmedicated patients and healthy adults. Six paranoid patients were taking an atypical and three a typical neuroleptic, whereas five undifferentiated patients were taking an atypical and four a typical neuroleptic.

The ERP data for 14 unmedicated patients were compared to those for 14 healthy adults who matched these patients in gender, age, education, and response hand (Table 1). Four of the unmedicated patients had a diagnosis of paranoid schizophrenia, six undifferentiated schizophrenia, two schizoaffective-depressed, and two schizoaffective-bipolar.¹ These patients did not receive neuroleptic medication for about 2 weeks before testing (mean = 15.8 days, SD = 8.7).

¹ An analysis was also performed to compare ERPs of 20 patients who had a schizoaffective disorder and 20 schizophrenic patients who were matched in gender, age, education, and total BPRS scores. Four schizoaffective patients and three schizophrenic patients were unmedicated, and the remaining patients in these groups were receiving comparable typical or atypical neuroleptics. Analysis of variance of the factor scores corresponding to N1, N2, P300, and P420 indicated that there was no significant difference between the schizoaffective and schizophrenic groups in amplitude of these components.

Wechsler Memory Scale

The Wechsler Memory Scale-Revised (Wechsler 1987) was administered to 47 of the patients. Three subtests were utilized: 1) logical memory provides a measure of immediate verbal memory; 2) verbal paired associates assesses learning to associate eight word pairs; and 3) visual reproduction measures immediate recall of designs.

ERP Recording and Analyses

Details of ERP recording and analyses are given elsewhere (Kayser et al 2001). Briefly, participants listened to a series of tones or syllables in six 50-trial blocks (60 targets, 240 nontargets), in which only two different tones or syllables (infrequent targets and frequent standards) were presented in a block. They were instructed to press a button as quickly as possible after infrequent, target stimuli. Response hand was counterbalanced across participants.

Averaged ERP waveforms for the total sample of 98 participants (66 patients and 32 control subjects) in our study were submitted to a principal components analysis (PCA). The PCA factor loadings for the five components used in this study (N100, N200, P300, P420, and S870) are shown in Figures 1 and 2 for correspondence to the ERP waveforms (see Kayser et al 2001 for additional details).²

Statistical Analyses

Principal component analysis factor scores for target stimuli were submitted to repeated measures analysis of variance (ANOVA) with group (paranoid/undifferentiated or unmedicated patients/control subjects) and response hand (left/right) as between-subjects factors, and task (phonetic/tonal), electrode site, and hemisphere as within-subjects factors. In accordance with

² Separate PCAs were also calculated for the 26 patients who entered into the paranoid versus undifferentiated comparison and for the 28 participants who entered into the unmedicated patients versus control subjects comparison. The factors for each PCA closely matched the originally extracted factors for the total sample, which suggests that these factors are stable and reproducible across data sets.

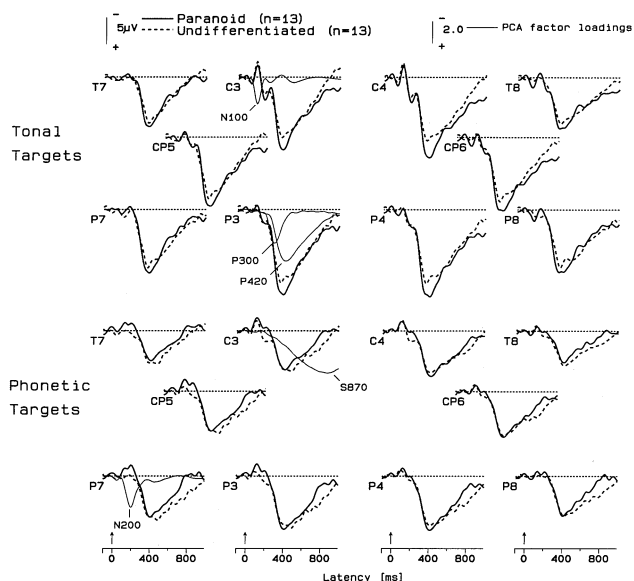


Figure 1. Grand average event-related potential (ERP) waveforms at central and parietal recording sites for tonal and phonetic target stimuli, comparing 13 paranoid and 13 matched undifferentiated patients. Distinct ERP components closely corresponded to the extracted principal components analysis (PCA) factors, as is evident from the time course of the PCA factor loadings (see thin solid lines at sites C3 and P3 for tonal targets, and at sites C3 and P7 for phonetic targets).

Kayser et al (2001), repeated-measures ANOVA were conducted for a subset of recording sites, at which PCA factor scores were largest and most representative of the associated ERP component (see Table 2). Greenhouse-Geisser epsilon (ϵ) correction was used to compensate for violations of sphericity when appropriate. The sources of interactions were systematically examined through simple effects (BMDP-4V; Dixon 1992). Significant group differences in topography were confirmed after scaling the amplitudes for each task across hemisphere and site (McCarthy and Wood 1985; Ruchkin et al 1999).

Pearson correlations were computed to examine relationships between ERPs, clinical ratings, and Wechsler Memory Scale scores. Significant correlations were validated using nonparametric Spearman rank-order correlations. Correlations were performed separately for each task at the most robust recording sites for each ERP component and task (see Table 3).

Results

Paranoid Versus Undifferentiated Subtypes

There was no difference in performance between paranoid and undifferentiated patients in either task. An ANOVA of the N100 factor scores also showed no difference between groups (Table 2). There was a task-dependent difference in N2 amplitude between groups at the frontocentral sites (Figure 1), which was reflected in a Group \times Task \times Site interaction. Analyses of simple effects revealed significant

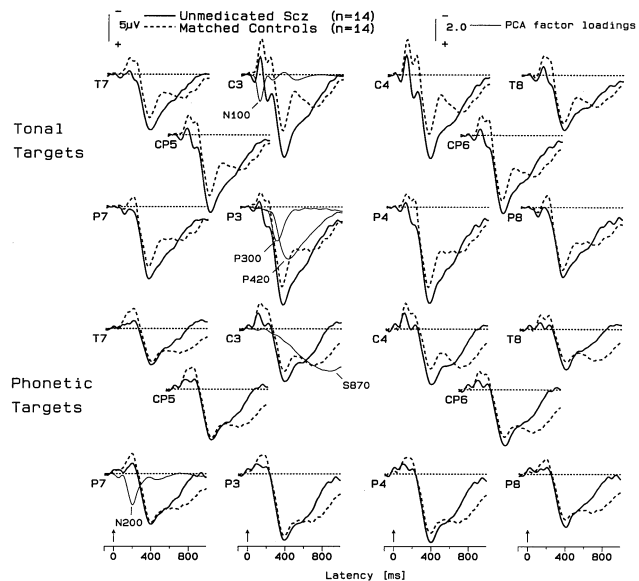


Figure 2. Grand average average event-related potential (ERP) waveforms at central and parietal recording sites for tonal and phonetic target stimuli, comparing 14 unmedicated schizophrenic patients and 14 matched healthy adults.

Group \times Task interactions at sites FC5/6 [$F(1,22) = 5.44, p < .05$] and C3/4 [$F(1,22) = 4.47, p < .05$], but not at other sites. Paranoid patients showed greater N2 when compared to undifferentiated patients at frontocentral sites in the phonetic task [FC5/6; $F(1,22) = 7.59, p = .01$; C3/4; $F(1,22) = 5.46, p < .05$], but not in the tonal task. Moreover, paranoid patients had greater N2 over left than right hemisphere at lateral temporoparietal sites [i.e., at T7/8, CP5/6, P7/8, and P9/10, all $F(1,22) > 4.50$, all $p < .05$] in the phonetic task, but not in the tonal task. In contrast, undifferentiated patients did not show a significant hemispheric asymmetry of N2 in either task. Although paranoid patients tended to have a larger late positive peak than undifferentiated patients in the tonal task (Figure 1), there was no significant difference between groups in factor scores for P300, P420, or S870.

Unmedicated Patients Versus Healthy Adults

There was no difference in performance between unmedicated patients and healthy adults. N1 tended to be smaller in unmedicated patients than in control subjects (Figure 2), but this difference did not achieve statistical significance [$F(1,24) = 3.58, p = .07$]. N2 amplitude was significantly reduced in the unmedicated patients compared to control subjects. This reduction was larger in the tonal than the phonetic task and was most marked at central sites, which is reflected by interactions involving Group, Task, and Site (Table 2). An ANOVA of P420 factor scores revealed a main effect of Group and a Group \times Task \times Hemi-

Table 2. Summary of *F*-Ratios (and ϵ Corrections) from Repeated Measures Analysis of Variance Performed on Principal Component Analysis Factor Scores for Target Stimuli Comparing Paranoid (*n* = 13) Versus Undifferentiated (*n* = 13) and Unmedicated Patients (*n* = 14) Versus Healthy Adults (*n* = 14)

Variable	df	Factor				
		N100	N200	P300	P420	S870
Paranoid vs. undifferentiated						
Group × Site	2,44					7.06 ^b (0.99)
Group × Site × Task	7,154		4.63 ^a (0.30)			
Unmedicated patients vs. healthy adults						
Group	1,24		15.98 ^c		5.01 ^a	6.16 ^b
Group × Task	1,24		6.75 ^a			
Group × Site	7,168		6.05 ^a (0.21)			
Group × Site × Task	7,168		9.46 ^c (0.24)			
Group × Task × Hemisphere	1,24				9.28 ^b	

Only significant *F*-ratios with *p* < 0.05 involving Group are reported.

Task = tonal/phonetic; Hemisphere = left/right; Site = electrode location (representative sites [cf. Kayser et al 2001] were, for N100: F3/4, C3/4; for N200: FT9/10, FC5/6, T7/8, C3/4, TP9/10, CP5/6, P7/8, P9/10; for P300, P420, and S870: P3/4, P7/8, CP5/6).

^a*p* < 0.05.

^b*p* < 0.01.

^c*p* < 0.001.

sphere interaction. This late P3 subcomponent was more positive in unmedicated patients than in control subjects, and this difference was greater in the tonal than phonetic task, particularly over left hemisphere sites. In contrast, the late positive slow wave (S870) was significantly smaller in unmedicated patients than in control subjects.³

Correlational Analyses

Greater severity of illness, as indexed by total BPRS scores, was associated with smaller early P3 in the tonal task and late P3 in the phonetic task (Table 3). This inverse relationship was also seen between severity of negative symptoms and early P3 in both tasks. Positive symptoms were not significantly correlated with early or late P3. Nor were N1, early P3, or late P3 related to measures of Thinking Disturbance on the BPRS. There was also no significant correlation between log TDI scores and early or late P3 in either task. Because thought disorder has been hypothesized to be related to reductions of P3 over left

³ The ANOVA performed on the vector-scaled ERP amplitudes for each task across all 30 recording sites (McCarthy and Wood 1985; Ruchkin et al 1999) yielded somewhat smaller effects for the N200 interactions of Group × Site [*F*(7,168) = 2.81, *p* = .08, ϵ = .25] and Group × Site × Task [*F*(7,168) = 3.90, *p* = .03, ϵ = .25], and the Group × Task × Hemisphere interaction for P420 [*F*(1,24) = 3.75, *p* = .06], indicating that these group differences in ERP topography were partially dependent on the overall group differences of N200 and P420 amplitude.

Table 3. Pearson Correlations of Symptom Severity and Verbal Memory with Event-Related Potential Components (PCA Factor Scores)

	Tonal				Phonetic			
	N100	N200	P300	P420	N100	N200	P300	P420
BPRS ^a	—	—	-0.27	-0.10	—	—	-0.14	-0.28
PANSS: Negative ^a	—	—	-0.36	-0.09	—	—	-0.28	-0.18
PANSS: Positive ^a	—	—	-0.08	-0.05	—	—	0.01	-0.14
Thinking Disturbance ^a	0.15	—	-0.18	-0.08	0.17	—	-0.18	-0.23
TDI total ^b	-0.03	—	-0.15	0.03	-0.05	—	-0.15	-0.07
Wechsler Memory:								
Verbal Associates ^c	—	0.06	0.24	0.30	—	-0.20	0.25	0.17
Logical Memory ^d	—	0.01	0.27	0.14	—	-0.30	0.15	0.07
Visual Memory ^c	—	0.04	0.09	0.19	—	-0.18	-0.07	0.25

Only predicted correlations are shown. Correlations given in bold face indicate a significance level of *p* ≤ 0.05 (two-tailed). Correlations were computed for mean PCA factor scores at representative recording sites (cf. Kayser et al 2001): for N100, from frontocentral sites (Fz, Cz, F3/4, C3/4); for N200, from lateral sites over the right hemisphere for the tonal task (FT10, FC6, T8, C4, TP10, CP6, P8, P10), over the left hemisphere for the phonetic task (FT9, FC5, T7, C3, TP9, CP5, P7, P9); for P300 and P420, from parietal sites (Pz, P3/4, P7/8, CP5/6).

PCA, principal component analysis; BPRS, Brief Psychiatric Rating Scale; PANSS, Positive and Negative Symptoms Scale.

^a*n* = 60.

^b*n* = 42.

^c*n* = 46.

^d*n* = 47.

temporal cortex (McCarley et al 1993), correlations were also performed focusing on the left temporal site (T7). Again, there was no significant correlation between log TDI and either early or late P3 in either task ($r = -0.06$ to $-.11$, ns).

Verbal memory was associated with P3 amplitude in the tonal task but not in the phonetic task. Larger late P3 amplitude was associated with better verbal paired-associates performance. A similar trend was also evident for larger early P3 to be associated with better immediate recall on the logical memory subtest ($p = .07$). In the phonetic task, larger N2 from lateral sites over the left hemisphere was associated with better logical memory performance.

Discussion

There was no difference in P3 between the paranoid and undifferentiated subtypes of schizophrenia in either tonal or phonetic oddball tasks. This agrees with the findings of prior studies using oddball tasks with tones (Boutros et al 1997; St Clair et al 1989). Although there was also no difference between these subtypes in N1 or N2 during a tonal oddball task, paranoid patients showed greater N2 at frontocentral sites in a phonetic task. This is of interest given reports of better verbal processing in paranoid than undifferentiated schizophrenia (Seltzer et al 1997). The likelihood that larger N2 to syllables in paranoid patients may indicate more intact left hemispheric language processing is supported by an additional finding. Paranoid patients showed greater N2 over left than right temporoparietal sites in the phonetic task, consistent with findings in healthy adults (Kayser et al 1998), whereas undifferentiated patients did not. Dichotic listening studies have similarly found larger left hemisphere advantages in paranoid than nonparanoid schizophrenia (Friedman et al in press; Gruzelier and Hammond 1980; Nachson 1980).

In accordance with prior findings (Ford et al 1999; Turetsky et al 1998), greater severity of illness was associated with smaller P3 amplitude in schizophrenic patients. The inverse relationship between clinical severity and P3 was evident for negative symptoms but not positive symptoms. Neither P3 nor N1 amplitude was related to thought disorder, as indexed by TDI scores, or to Thinking Disturbance scores on the BPRS. It is difficult to account for the difference in findings of this study and those finding a relationship between P3 and thought disorder (McCarley et al 1993; Shenton et al 1989). It could stem from a difference in patient characteristics (e.g., in severity of illness or chronicity), or a difference in oddball paradigms. Also, the correlations observed between P3 and total BPRS scores or negative symptoms were relatively weak, which may reflect the marked individual differences

in P3 amplitude and the cross-sectional nature of this study (Mathalon et al 2000). We have previously reported stronger correlations between P3 amplitude and behavioral performance, particularly in the phonetic oddball task (Kayser et al 2001). Therefore, individual differences in P3 among patients reflect not only symptom severity but also cognitive disturbances (Pallanti et al 1999).

The association of P3 and cognitive function was also evident in the correlation of greater P3 amplitude in a tonal oddball task and better verbal paired-associates memory, which agrees with prior findings (Nagasawa et al 1999). P3 reduction over the left temporal region and associative memory loss in schizophrenia were associated with reduced volume of the posterior superior temporal gyrus (McCarley et al 1993; Nestor et al 1993). P3 in our phonetic task was not, however, correlated with verbal paired-associates performance, which might be expected given a left-lateralized deficit. Larger N2 over left hemisphere sites in the phonetic task was associated with better verbal memory on the logical memory subtest. This relationship is understandable given the role of the left temporal lobe in recognition memory and N2 for word stimuli (Kayser et al 1999).

Unmedicated schizophrenic patients showed a marked reduction of N2 amplitude, despite the absence of any difference in behavioral performance. This indicates that the N2 reduction in schizophrenia is *not* a byproduct of medication, lack of attention, or poorer performance in patients. Unlike N2, amplitude of N1, which reflects earlier sensory and attentional processing, was not significantly reduced in unmedicated patients. Pfefferbaum et al (1989) similarly found that schizophrenic patients off medication did not differ from control subjects in N1. For the unmedicated patients, ERPs agreed with the full sample in showing no reduction of the P3 potential (Kayser et al 2001). Although some studies have found an increase in P3 amplitude during neuroleptic treatment (Coburn et al 1998; Umbricht et al 1998), it is unlikely that the medication status alone could account for the absence of a P3 reduction for schizophrenic patients in our study.

This work was supported by grants MH50715 and MH59342 from the National Institute of Mental Health.

We thank Paul Leite, Regan Fong, Jennifer Bunn-Watson, Barbara Stuart, Scott Yale, Raymond Goetz, and Nilabja Bhattacharya for help with data collection. Software developed by Charles L. Brown to display ERP waveforms is gratefully acknowledged.

References

- American Psychiatric Association (1994): *Diagnostic and Statistical Manual of Mental Disorders* 4th edition. Washington, DC: American Psychiatric Press.
- Boutros N, Nasrallah H, Leighty R, Torello M, Tueting P, Olson

- S (1997): Auditory evoked potentials, clinical vs. research applications. *Psychiatry Res* 69:183-195.
- Coburn KL, Shillcutt SD, Tucker KA, Estes KM, Brin FB, Merai P, Moore NC (1998): P300 delay and attenuation in schizophrenia: Reversal by neuroleptic medication. *Biol Psychiatry* 44:466-474.
- Dixon WJ, editor (1992) *BMDP Statistical Software Manual: To Accompany the 7.0 Software Release*. Berkeley: University of California Press.
- Ford JM, Mathalon DH, Marsh L, Faustman WO, Harris D, Hoff AL, et al (1999): P300 amplitude is related to clinical state in severely and moderately ill patients with schizophrenia. *Biol Psychiatry* 46:94-101.
- Friedman MS, Bruder GE, Nestor PG, Stuart B, Amador XF, Gorman JM (in press): Perceptual asymmetries in schizophrenia: subtype differences in left hemisphere dominance for dichotic fused words. *Am J Psychiatry*
- Gruzeliar JH, Hammond NV (1980): Lateralized deficits and drug influences on the dichotic listening of schizophrenic patients. *Biol Psychiatry* 15:759-779.
- Johnston MH, Holzman PS (1979): *Assessing Schizophrenic Thinking*. San Francisco: Jossey-Bass.
- Kay SR, Opler LA, Fishbein A (1992): *Positive and Negative Syndrome Scale (PANSS) Rating Manual*. Toronto: Multihealth System Inc.
- Kayser J, Bruder GE, Friedman D, Tenke CE, Amador XF, Clark SC, et al (1999): Brain event-related potentials (ERPs) in schizophrenia during a word recognition memory task. *Int J Psychophysiol* 34:249-265.
- Kayser J, Bruder GE, Tenke CE, Stuart BK, Amador XF, Gorman JM (2001) Event-related potentials (ERPs) in schizophrenia for tonal and phonetic oddball tasks. *Biol Psychiatry* 49: 832-847.
- Kayser J, Tenke CE, Bruder GE (1998): Dissociation of brain ERP topographies for tonal and phonetic oddball tasks. *Psychophysiology* 35:576-590.
- Mathalon DH, Ford JM, Pfefferbaum A (2000) Trait and state aspects of P300 amplitude reduction in schizophrenia: A retrospective longitudinal study. *Biol Psychiatry* 47:434-449.
- McCarley RW, Shenton ME, O'Donnell BF, Faux SF, Kikinis R, Nestor PG, et al (1993): Auditory P300 abnormalities and left posterior superior temporal gyrus volume reduction in schizophrenia. *Arch Gen Psychiatry* 50:190-197.
- McCarthy G, Wood CC (1985): Scalp distributions of event-related potentials: An ambiguity associated with analysis of variance models. *Electroencephalogr Clin Neurophysiol* 62: 203-208.
- Nachshon I (1980): Hemispheric dysfunctioning in schizophrenia. *J Nerv Ment Dis* 168:241-242.
- Nagasawa T, Kamiya T, Kawasaki Y, Higashima M, Urata K, Sakai N, Koshino Y (1999): The relationship between auditory ERP and neuropsychological assessments in schizophrenia. *Int J Psychophysiol* 34:267-274.
- Nestor PG, Shenton ME, McCarley RW, Haimson J, Smith RS, O'Donnell B, et al (1993): Neuropsychological correlates of MRI temporal lobe abnormalities in schizophrenia. *Am J Psychiatry* 150:1849-1855.
- Pallanti S, Quercioli L, Pazzagli A (1999): Basic symptoms and P300 abnormalities in young schizophrenic patients. *Compr Psychiatry* 40:363-371.
- Pfefferbaum A, Ford JM, White PM, Roth WT (1989): P3 in schizophrenia is affected by stimulus modality, response requirements, medication status, and negative symptoms. *Arch Gen Psychiatry* 46:1035-1044.
- Ruchkin DS, Johnson R Jr, Friedman D (1999): Scaling is necessary when making comparisons between shapes of event-related potential topographies: A reply to Haig, et al. *Psychophysiology* 36:832-834.
- Seltzer J, Conrad C, Cassens G (1997): Neuropsychological profiles in schizophrenia: Paranoid versus undifferentiated distinctions. *Schizophr Res* 23:131-138.
- Shenton ME, Faux SF, McCarley RW, Ballinger R, Coleman M, Torello M, Duffy FH (1989): Correlations between abnormal auditory P300 topography and positive symptoms in schizophrenia: A preliminary report. *Biol Psychiatry* 25:710-716.
- Solovay MR, Shenton ME, Holzman PS, Gasperetti C, Carpenter JT, Coleman M, Kestenbaum E (1986): Scoring manual for the thought disorder index. *Schizophr Bull* 12:483-496.
- St Clair D, Blackwood D, Muir W (1989): P300 abnormality in schizophrenic subtypes. *J Psychiatr Res* 23:49-55.
- Turetsky BI, Colbath EA, Gur RE (1998): P300 subcomponent abnormalities in schizophrenia: I. Physiological evidence for gender and subtype specific differences in regional pathology. *Biol Psychiatry* 43:84-96.
- Umbricht D, Javitt D, Novak G, Bates J, Pollack S, Lieberman J, Kane J (1998): Effects of clozapine on auditory event-related potentials in schizophrenia. *Biol Psychiatry* 44:716-725.
- Wechsler D (1987): *Wechsler Memory Scale-Revised Manual*. New York: Psychological Corp.