ISSN 1392–0359. PSICHOLOGIJA 2006 33

EVALUATION OF THE NEW PARAMETERS OF AUDITORY EVOKED POTENTIALS (AEPs) IN PATIENTS WITH SCHIZOPHRENIA SPECTRUM DISORDERS

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The aim of the present study was to evaluate the new P300 parameters on patients with schizophrenia spectrum disorders and to compare their reliability with the commonly used P300 latency and amplitude. 56 healthy human subjects and 22 patients with schizophrenia spectrum disorders were studied. The following new parameters were considered: L_{P300}/A_{P300}, identification time (IT), steepness of cognitive complex (SCC), P300 energy, speed of descending part of P300 slope (SDS), and its parameters A, B; the same parameters of subtraction wave – sSDS, sA and sB. Some of the proposed parameters showed a more significant statistical difference in differentiating patients from controls than did the commonly used measures (latency and amplitude). We suggest that the parameters proposed by us could be helpful in differentiating schizophrenia disorder patients from controls. The use of the subtraction curve could be more preferable than the use of the deviant one.

Key words: *AEPs, P300 wave, schizophrenia, schizophrenia spectrum disorders.*

Abbreviations: E_{P300} – *P300 energy; IT – identification time; SDS – speed of descending part of P300 slope; SCC – steepness of cognitive complex; sSDS – speed of descending part of P300 slope of subtraction curve.*

AEPs are electroencephalographic changes time-locked to the sensory stimuli, and they non-invasively provide neurophysiological data on human brain activity with a time resolution of milliseconds. The N2 and P300 waves are elicited by the active detection of deviant tones in a sequence of standard ones (Sutton et al., 1965) and give an objective estimate of the time required to evaluate deviant stimuli (Pfefferbaum et al., 1995). The P300 amplitude is referred to the allocation of brain energy resources (Kok, 1997), and the N2 amplitude may be related to the effort required to discriminate the target stimuli (Fitzgerald and Picton, 1983; Näätänen and Picton, 1986).

Schizophrenia patients show attenuated amplitudes of N2 and P300 and, further, a delayed latency of P300 (Blackwood et al., 1987) indicating disturbances in information processing. Patients with schizophrenia, spectrum disorders share some phenotypic similarities with schizophrenia, including personality traits (Lenzenweger, 1994), neuropsychological deficits (Kremen et al., 1994), psychophysiological deficits (Matthysse et al., 1986), and cognitive disturbances (Bredgaard and Glenthoj, 2000; Lichtermann et al., 2000). Abnormal auditory P300 responses in patients with schizophrenia spectrum disorders have confirmed similarities with schizophrenia (Kimble et al., 2000; Korostenskaja et al., 2005; Michie et al., 2002). Furthermore, R. L. Trestman et al. (1996) showed that the changes in auditory N1, P2, N2 and P300 components in patients with schizotypal personality disorder were intermediate between schizophrenia patients and healthy subjects.

However, many of the problems associated with the clinical application of the P300 potential are recognized (Barrett, 2000). These include a broad inter-subject variability of peak latencies and amplitudes in control groups, as well as apparent non-specificity of P300 tests. The search for the features that could be more stable and reliable for schizophrenia patients became the purpose of investigations. In our previous papers (Korostenskaja et al., 2003a,b) we have discussed possibilities of introducing new P300 parameters in healthy subjects (Korostenskaja et al., 2003a) and new parameters for mismatch negativity (MMN) evoked potential in patients with schizophrenia spectrum disorders (Korostenskaja et al., 2003b).

We divided novel measures into two groups: the first – "derivatives" – included measures which related amplitudes and latencies of a component under study, and the second – "extrapolation" – group included measures based on the extrapolated line of the descending part of the P300 wave.

One of newly suggested measurements is the speed of the descending slope (SDS) of the P300 component. It could reflect some specific aspect of active attention to the presented stimuli. This measurement is commonly used in plethysmographic recordings. M. Korostenskaja et al. (2003b) was using it in MMN measurements. We suppose that introduction of all these new P300 measurements could be helpful in solving MMN problems and useful in the interpretation of clinical data.

The aim of the present study was to evaluate the new P300 parameters in patients with schizophrenia spectrum disorders and to compare their reliability with, latency and amplitude, the most frequently used N2 and P300 parameters.

Methods

Subjects

We have studied two main groups of subjects: 22 patients with schizophrenia spectrum disorders (16 females), mean age 29.9 years (SD 10.6, range 18–55 years), and 56 healthy controls (40 females), mean age 33.8 years (SD 11.6, range 20–59 years). Diagnoses in all 22 cases were made according to the ICD-10 (International Classification of Diseases, World Health Association, 1992) by psychiatrists. The diagnosis of paranoid schizophrenia (F20.0) was established in 5 cases, schizoaffective disorder of depressive type (F25.1) in 7 cases, 2 patients had schizoaffective disorder of mixed type (F25.2), 1 case was considered as delusional disorder (F22.0) and 7 patients had schizotypal disorder (F21). Nine patients were hospitalized for the first time. Exclusion criteria for psychiatric patients were an organic pathology of the central nervous system (tumours, etc.) and the history of alcohol dependence. Healthy controls had no known neurological or psychiatric disorders. The study was performed at the Republican Vilnius Psychiatric Hospital (Vilnius, Lithuania). It was approved by the Ethics Committee of the hospital. The subjects gave their written informed consent to participate in the study.

Medication

At the moment of AEP recording 11 patients were neuroleptic naive, 7 neuroleptic free (1 for at least half a year, and 6 for at least 1 month), 1 patient was treated with trifluoperazine 30 mg/day, 1 patient with haloperidol decanoate 50 mg. One of the patients received benzodiazepines. Four patients additionally received the serotonin reuptake inhibitor citalopram (20 mg/day). For 3 patients an anticholinergic drug trihexyphenidylum (4 mg/day) was added. Clinical symptoms were evaluated with PANSS (Kay et al., 1987).

AEP recording

All data were acquired in an electrically shielded room. The recording sessions were always carried out between 9 a.m. and 2 p.m. The AEPs were recorded with a 32-channel EEG device (Galileo NT, by EBNeuro, Italy) (bandpass 0.01–30 Hz) from Cz site (according to the 10/20 international system) using Ag/AgCl electrodes. Ear electrodes served as a reference for all electrodes and the ground electrode was attached to the forehead. AEPs were acquired during active oddball paradigm. Pure tones were binaurally presented via headphones at the intensity 60dB. Standard tones had the frequency of 2000 Hz and duration of 50 ms. Deviant tones had the same duration and frequency (1000 Hz). The probability of tones was 80% for standards and 20% for deviants. During the recording at least 30 deviant stimuli were presented. The subjects were asked to count in mind all deviant stimuli and then to report the sum. The inter-stimulus interval (ISI) was 1500 ms, the analysis period was 1000 ms. The paradigm consisted of two blocks with a 1-minute interval. The signal re-

jection threshold was set for an amplitude of more than 50 μV.

Data analysis

All patients were divided into two subgroups: patients with both types of schizoaffective disorder (9 cases) and all the other patients (13 cases). The latter subgroup is named in this paper "schizophrenia group". We compared the mean values of the study parameters between the control group and the group of patients. Both subgroups of patients were also compared with controls. And, finally, both subgroups of patients were compared with each other.

General measures

In the responses to the deviant tone, the later negative (N2) – positive (P300) complex was identified. Two main parameters were measured: peak latency and amplitude. The amplitudes were measured as peak-to-peak voltages (Spehlmann, 1985; Reinsel et al., 1995) for P2–N2 (called N2 amplitude) and N2-P300 (P300 amplitude).

New parameters

"Derivative" group

The ratio of P300 latency and amplitude (L_{P300}/A_{P300}), stimulus identification time (IT), steepness of cognitive complex (SCC), and energy of P300 wave (E_{P300}) were measured (Слезин и др., 2001; Korostenskaja et al., 2003a). IT was measured as the difference between P300 and N2 latency ($IT = L_{P300} - L_{N2}$). SCC was measured as the ratio of difference between the N2 and P300 amplitudes and IT ($SCC = (A_{P300} - A_{N2})/IT$). E_{P300} was calculated by multiplication of P300 amplitude and latency ($E_{P300} = L_{P300} * A_{P300}$).

"Extrapolation" group

As applied for MMN response (Korostenskaja et al., 2003b), the speed of the descending part of the P300 slope (SDS) and A, B parameters of the extrapolation line were calculated. SDS was calculated in the following way: the descending slope of P300 wave from the point of slope rise inset to the maximum of the curve was approximated by a line (fig. 1), and the fluxion ($\Delta y/\Delta x$)

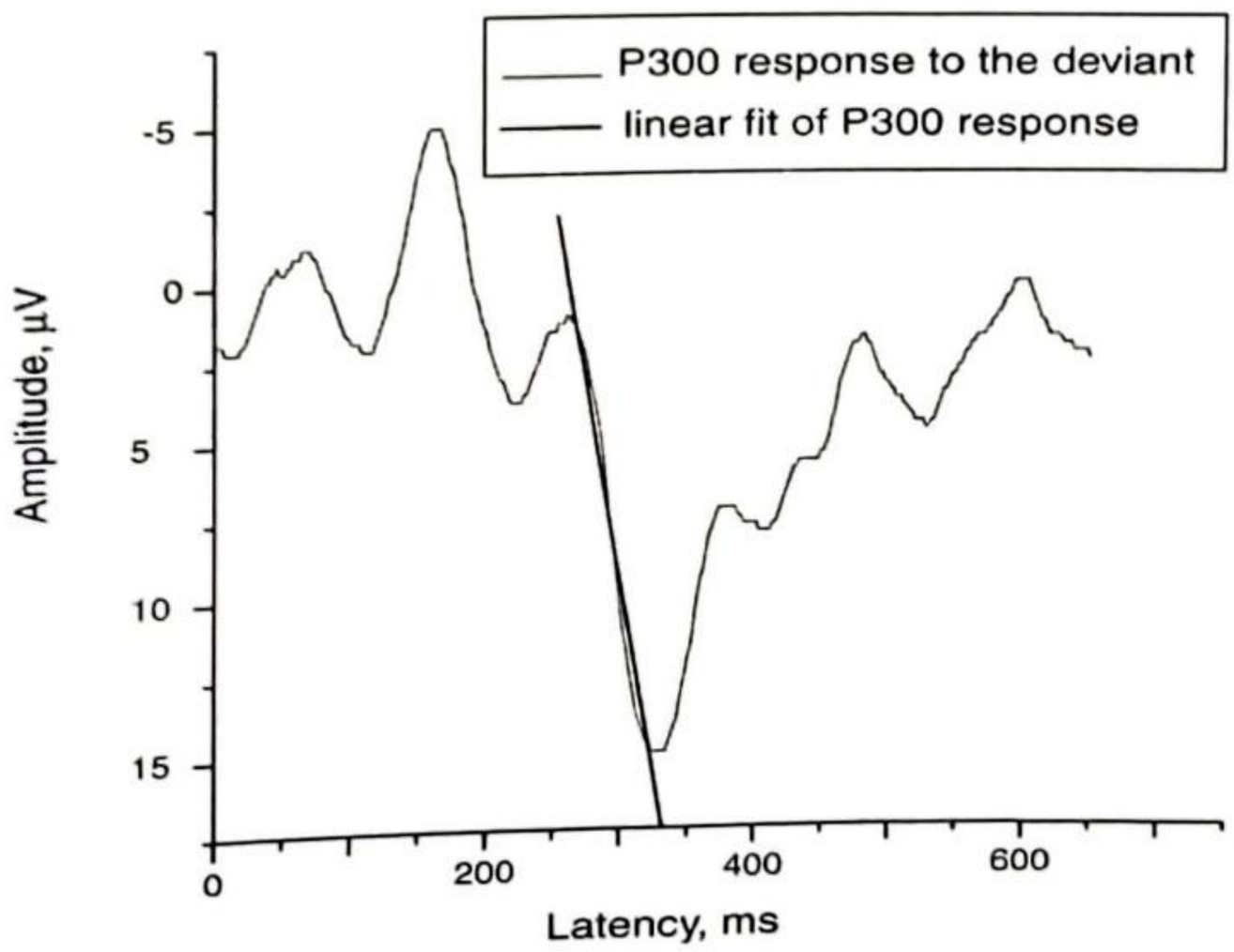

Fig. 1. ***Extrapolation line of P300 wave. Speed of descending part ($\Delta y/\Delta x$) of P300 slope (SDS) and A, B parameters of extrapolation line formula ($y = Ax + B$) were used in the study***

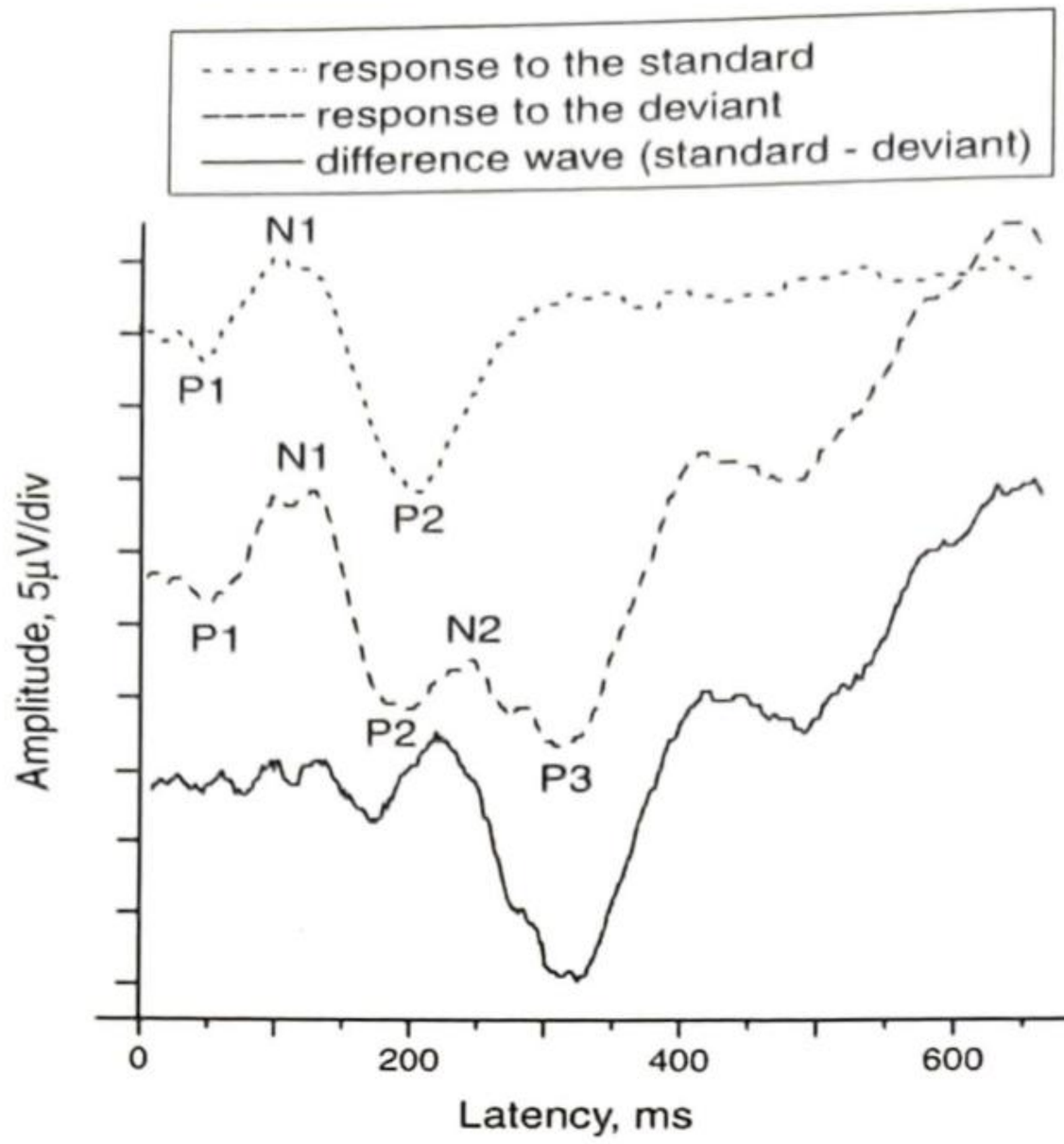

Fig. 2. ***Schematic illustration of the difference wave (subtraction curve). The vertical (y) axis is arbitrary and presented only to illustrate the result of subtraction procedure***

of the extrapolation line was calculated. The A, B parameters were taken from the equation of the extrapolation line: $y = Ax + B$, where A is the angle of the extrapolation line and B is the value of the P300 amplitude at the point of the intersection of the extrapolation line. The same parameters were calculated for the subtracted P300 wave (the difference between the curves of responses to deviant and standard tones – fig. 2), marked as sSDS, sA and sB.

Statistical analysis

Parametric statistics with T-test was applied to data with normal distribution, and in an opposite case the non-parametric Mann–Whitney U-test was performed. All calculations were carried out using STATISTICA 6 software package. When comparing the groups the equality of variance was tested, and necessary corrections were made when the variances differed significantly.

Results

All main calculated values of the parameters studied are presented in Tables 1 and 2.

Common measures – N2, P300 latency and amplitude

No statistically significant differences were found for N2 latency or for the P300 latency in patients when compared with controls.

Significant difference ($p = 0.01$) between patients and controls was found for the P300 amplitude, but not for the N2 amplitude.

Derivatives of N2, P300 latencies and amplitudes: L_{P300}/A_{P300}, IT, SCC, P300 energy

All derivatives of latencies and amplitudes of the cognitive complex (L_{P300} / A_{P300}, *IT, SCC, P300 energy)* showed a significant difference between patients and cotrols (tab. 1). The most sig-

Table 1. Main calculated values and formulas of P300 parameters studied (shows statistically significant values). Main values are presented for patients and healthy control groups*

Nr.	*Parameter, dimension*	*Brief name of the parameter*	*Formula*	*Healthy controls (mean ± SD) N = 56*	*Patients (mean ± SD) N = 22*	*P- significance level for the difference between patients and controls*
1	**Steepness of cognitive complex**, μV/ms	SCC	$(A_{N2} - A_{P300})/IT$	0.14 ± 0.07*	0.09 ± 0.06*	0.001*
2	**P300 latency and amplitude ratio**, ms/μV	L_{P300}/A_{P300}	L_{P300} / A_{P300}	28.86 ± 19.22*	51.86 ± 46.78*	0.003*
3	**P300 amplitude**, μV	A_{P300}	$A_{P300} - A_{N2}$	15.29 ± 7.37*	11.24 ± 7.87*	0.01*
4	**Stimulus identification time**, ms	IT	$L_{P300} - L_{N2}$	110.85 ± 19.11*	121.82 ± 22.72*	0.03*
5	**P300 energy**, μV*ms	E_{P300}	$A_{P300} * L_{P300}$	5158.76 ± 2432.04*	3767.6 ± 2443.08*	0.03*
6	**SAS for subtraction wave**, ms/μV	sSAS	Δy/Δx	–0.98 ± 0.01	–0.97 ± 0.02	0.12
7	**N2 latency**, ms	L_{N2}		228.64 ± 20.57	221.95 ± 28.5	0.25
8	**N2 amplitude**, μV	A_{N2}	$A_{P2} - A_{N2}$	5.84 ± 3.74	5.21 ± 4.20	0.36
9	**P300 latency**, ms	L_{P300}		339.14 ± 18.65	343.77 ± 29.85	0.4
10	**Angle coefficient of extrapolation line**	A	tgφ, φ – the angle between baseline and extrapolation line	67.17 ± 60.83	80.46 ± 62.06	0.45
12	**Amplitude of P300 at the point of intersection of extrapolation line**, μV	B		–0.32 ± 0.34	–0.35 ± 0.27	0.49
13	**Speed of ascending part of P300 slope**, ms/μV	SAS	Δy/Δx	–0.97 ± 0.01	–0.94 ± 0.19	0.68
14	**A for subtraction wave**	sA		97.3 ± 74.85	86.09 ± 56.46	0.81
15	**B for subtraction wave**, μV	sB		–0.42 ± 0.38	–0.37 ± 0.24	0.93

nificant difference (p = 0.001) was found for the SCC parameter (mean for patients 0.09 μV/ms, SD = 0.06, mean for controls 0.14 μV/ms, SD = 0.07) (fig. 3). In case of L_{P300}/ A_{P300}, the difference between patients (mean 51.87 ms/μV, SD = 46.78) and controls (mean 28.86 ms/μV, SD = 19.22) was also significant (p = 0.003) (fig. 4). The significance level of difference of SCC and L_{P300}/ A_{P300} between patients and controls was higher than of the P300 amplitude. For A_{P300} it was 0.01 (mean for schizophrenics 11.24 μV, SD 7.87; mean for controls 15.29 μV, SD 7.37) (fig. 5). The smallest significant differences were obtained for P300 energy (p = 0.03) and IT (p = 0.03). The mean P300 energy for patients was 3767.6, SD = 2443.06, and for controls 5158.76, SD = 2432.04, whereas the mean IT for patients was 121.82 ms, SD = 22.72, and

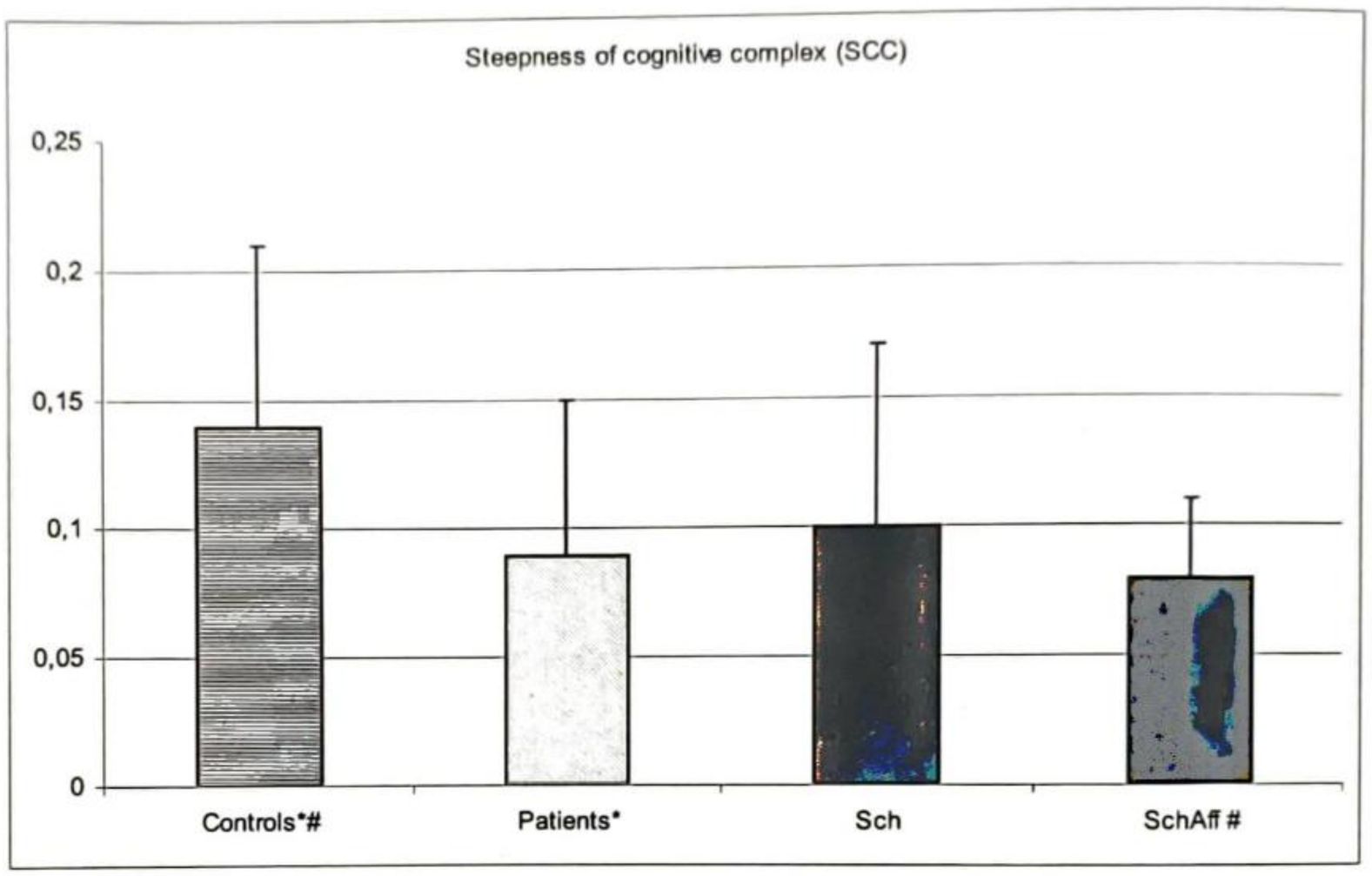

*Fig. 3. **Mean values and standard deviation (SD) of SCC for different groups of participants. Sch – subgroup of patients with schizophrenia, SchAff – subgroup of patients with schizoaffective disorder** (* and **# mark statistically significant differences between respective groups)***

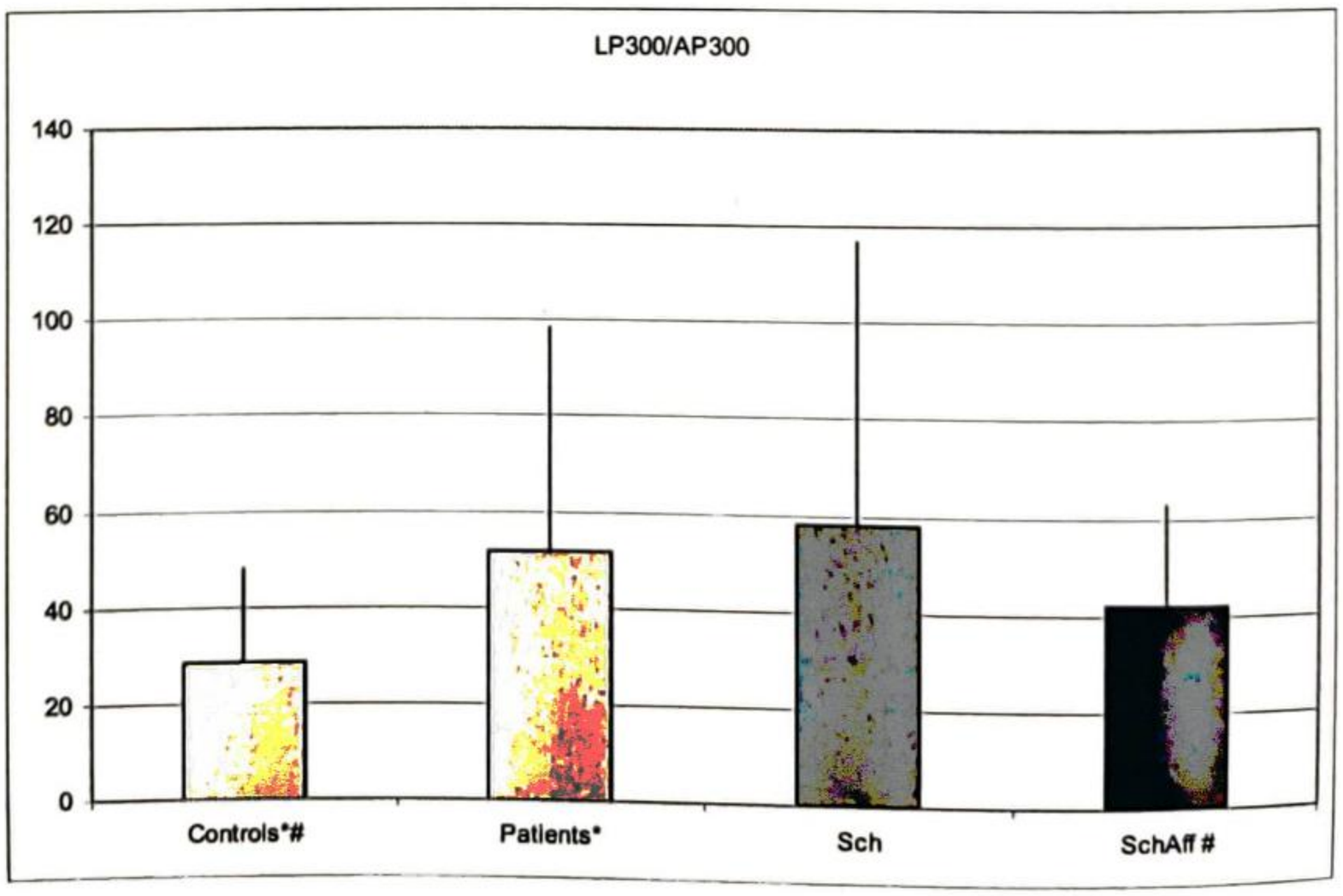

*Fig. 4. **Mean values and standard deviation (SD) of P300 amplitude and latency ratio for different groups of participants. Sch – subgroup of patients with schizophrenia, SchAff – subgroup of patients with schizoaffective disorder (* and # mark statistically significant differences between respective groups)***

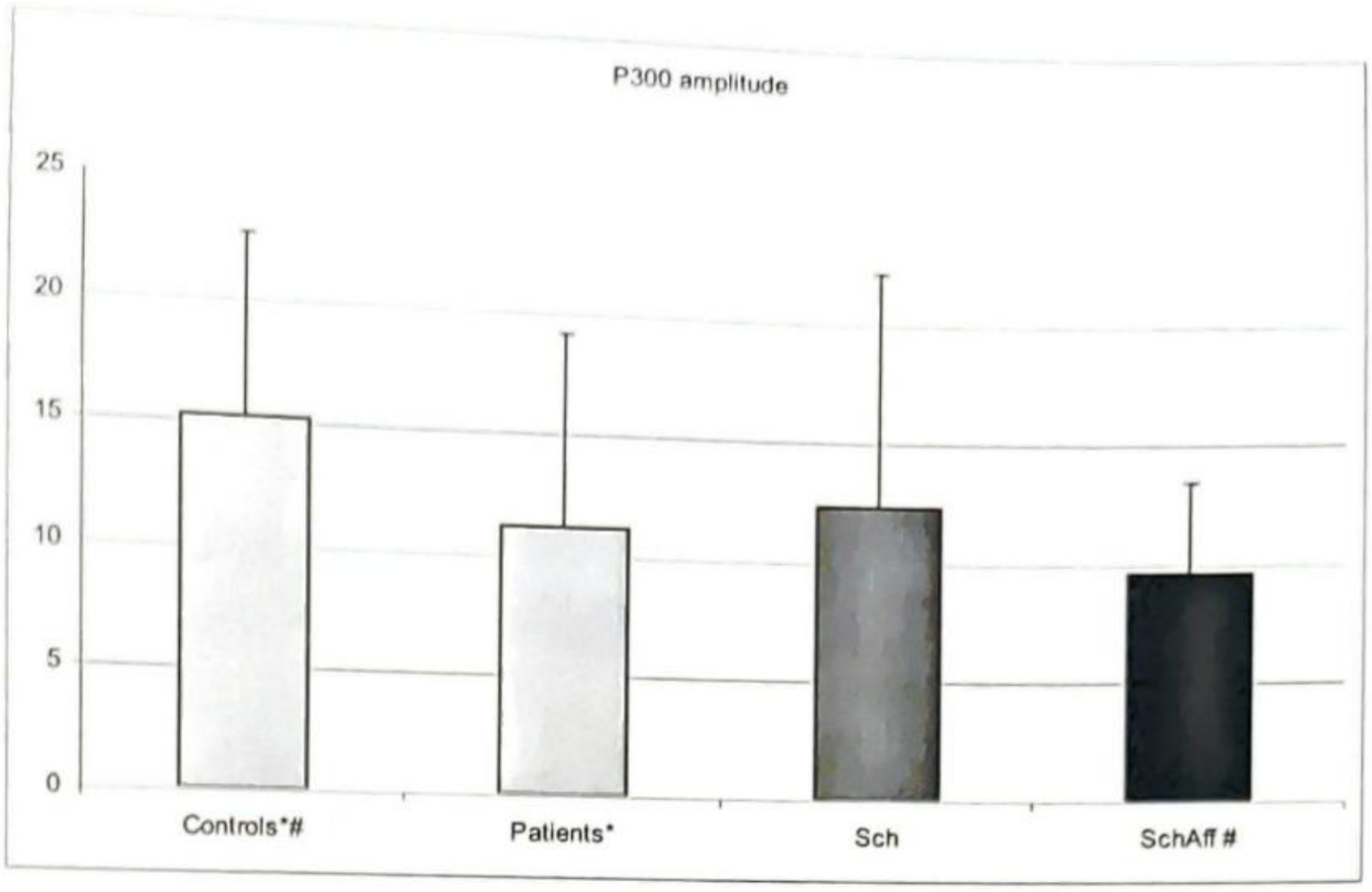

Fig. 5. Mean values and standard deviation (SD) of P300 amplitude for different groups of participants. Sch – subgroup of patients with schizophrenia, SchAff – subgroup of patients with schizoaffective disorder (and # mark statistically significant differences between respective groups)*

the mean IT for controls was 110.85, SD = 19.11.

Comparing schizophrenia and schizoaffective disorder subgroups with the control group (tab. 2), significant differences were found only for the schizoaffective disorder subgroup. They differed by the A_{P300} parameter (p = 0.01, mean for the schizoaffective disorder subgroup 9.64 μV, SD 3.84; mean for healthy controls 15.29 μV, SD = 7.37), by the L_{P300} / A_{P300} parameter (p = 0.01, mean for the schizoaffective disorder subgroup 42.46 ms/μV, SD 20.55; mean for healthy controls 28.86 ms/μV, SD = 19.22), and by the P300 energy parameter (p = 0.03, mean for the schizoaffective disorder subgroup 3311.73 μV*ms, SD 1283.76; mean for healthy controls 5158.76 μV*ms, SD = 2432.04).

Measurements based on extrapolated line of descending part of P300 wave: SDS, A, B, sSDS, sA and sB

None of these measures showed significant differences between patients and controls (see Table 1). Nevertheless, a significant difference for A, B and sA, sB parameters between patients with schizophrenia and schizoaffective disorder subgroups (Table 2) was found. For the B parameter, the significance level was 0.001 (mean for the schizophrenia subgroup 0.21 μV, SD 0.14; mean for the schizoaffective disorder subgroup 0.56 μV, SD 0.28), for sB the significance level was the same (mean for the schizophrenia subgroup 0.24, SD 0.13; mean the for schizoaffective disorder subgroup 0.56 μV, SD 0.24), for the parameter A p = 0.002 (mean for the schizophrenia subgroup 48.17, SD 33.99; mean for the schizoaffective disorder subgroup 127.09, SD 65.10) (fig. 6), and for sA p = 0.006 (mean for the schizophrenia subgroup 59.46, SD 32.62; mean for the schizoaffective disorder subgroup 124.56, SD 62.87).

Comparison between usually used and newly adopted parameters

The difference between patients and control groups was most significant for the newly adopted parameters such as L_{P300}/ A_{P300} and SCC rather than A_{P300}. Such parameters as IT and P300 energy had a less significance level than A_{P300}.

Table 2. Main calculated values and formulas of presented P300 parameters (shows statistically significant values, n.s. – not significant)*

Parameter, dimension	***Abbre-viation***	***Formula***	***Schizophrenia Subgroup (SchGr)*** *(mean ± SD) N = 13*	***Schizoaffective disorder subgroup (SchAffGr)*** *(mean ± SD) N = 9*	*P- significance level for difference between:*		
					SchGr and controls	*SchAffGr and controls*	*SchGr and SchAffGr*
N2 amplitude, μV	A_{N2}	$A_{P2} - A_{N2}$	5.42 ± 4.85	4.91 ± 3.30	n.s.	n.s.	n.s.
P300 energy, μV*ms	E_{P300}	$A_{P300} * L_{P300}$	4083.2 ± 3013.74	3311.73 ± 1283.76*	n.s.	0.03*	n.s.
P300 amplitude, μV	A_{P300}	$A_{P300} - A_{N2}$	12.34 ± 9.76	9.64 ± 3.84*	n.s.	0.01*	n.s.
P300 latency and amplitude ratio, ms/μV	L_{P300}/A_{P300}	L_{P300} / A_{P300}	58.37 ± 58.62	42.46 ± 20.55*	n.s.	0.01*	n.s.
Steepness of cognitive complex, μV/ms	SCC	$(A_{N2} - A_{P300})/IT$	0.1 ± 0.07	0.08 ± 0.03*	n.s.	0.001*	n.s.
Stimulus identification time, ms	IT	$L_{P300} - L_{N2}$	121.08 ± 25.81	122.89 ± 18.79	n.s.	n.s.	n.s.
N2 latency, ms	L_{N2}		220.85 ± 34.63	223.56 ± 18.14	n.s.	n.s.	n.s.
P300 latency, ms	L_{P300}		341.92 ± 34.75	346.44 ± 22.68	n.s.	n.s.	n.s.
Speed of descending part of P300 slope, ms/μV	SDS	Δy/Δx	–0.91 ± 0.24	–0.98 ± 0.01	n.s.	n.s.	n.s.
SDS for subtraction wave, ms/μV	sSDS	Δy/Δx	–0.97 ± 0.02	–0.96 ± 0.03	n.s.	n.s.	n.s.
Angle coefficient of extrapolation line	A	tgφ, φ – the angle between the baseline and extrapolation line	48.17 ± 33.99	127.09 ± 65.10*†	n.s.	0.008*	0.002†
A for subtraction wave	sA		59.46 ± 32.62	124.56 ± 62.87†	n.s.	n.s.	0.006†
Amplitude of P300 at the point of intersection of extrapolation line, μV	B		–0.21 ± 0.14	–0.56 ± 0.28*†	n.s.	0.007*	0.001†
B for subtraction wave, μV	sB		–0.24 ± 0.13	–0.56 ± 0.24*†	n.s.	0.03*	0.001†

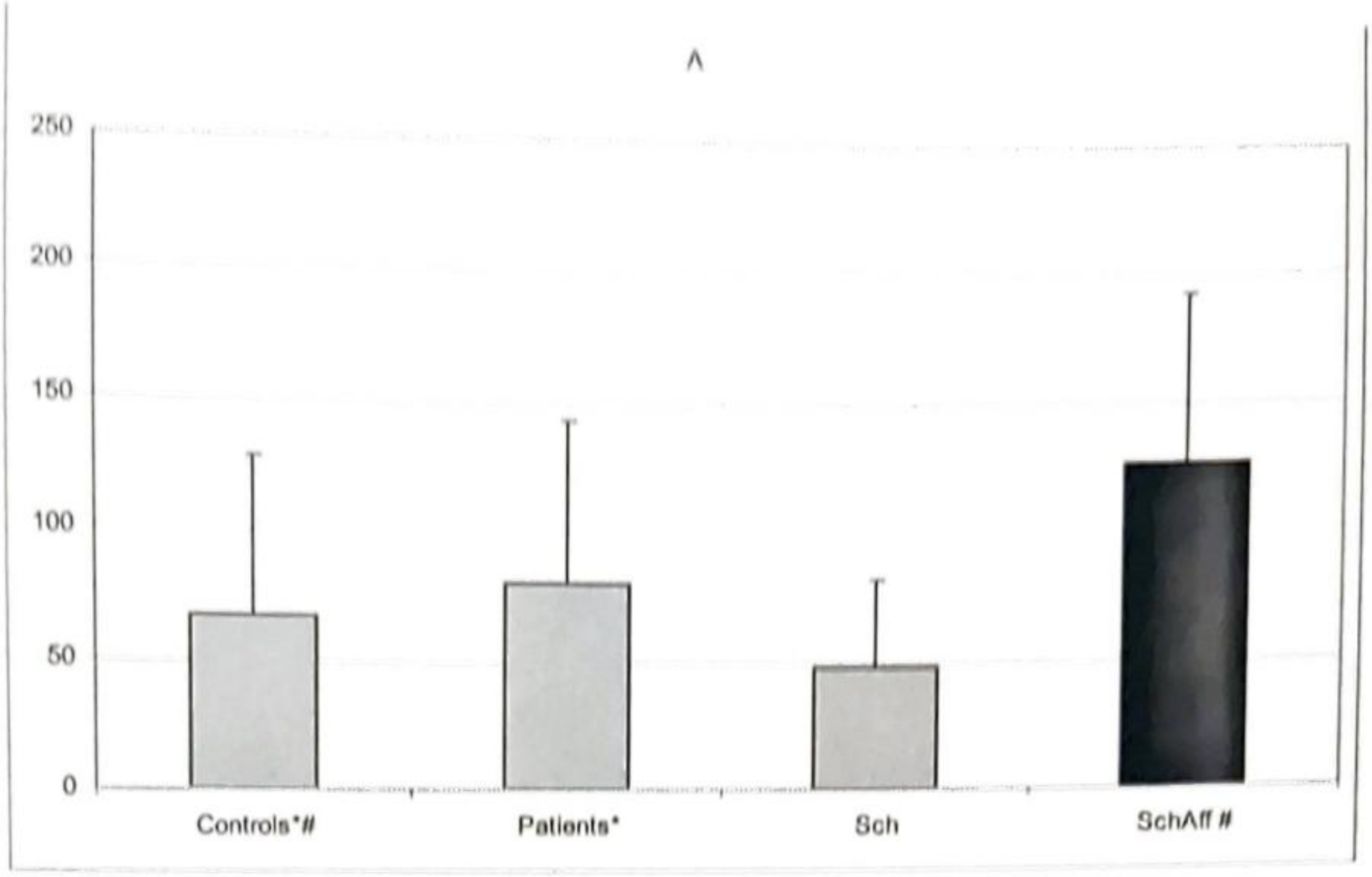

Fig. 6. Mean values and standard deviation (SD) of angle coefficient of extrapolation line (A) of P300 wave for different groups of participants. Sch – subgroup of patients with schizophrenia, SchAff – subgroup of patients with schizoaffective disorder (and # mark statistically significant differences between respective groups)*

Nevertheless, the variation of the newly adopted parameters was higher than of A_{P300}. Comparing the schizophrenia and schizoaffective disorder subgroups, the differences were found only for the newly adopted parameters such as A, B, sA and sB. The parameters of subtracted waveforms were more reliable than of non-subtracted, because their levels of statistical significance when comparing different groups were usually better.

Discussion

The results of measurement and comparison of the commonly used parameters have shown that only the amplitude of P300 wave (A_{P300}) proved as a valuable parameter in which the patients' group significantly differed from the control group. The significance of this parameter has been confirmed by other authors (Ford et al., 1994; Hegerl et. al, 1995; Juckel et al., 1996).

However, the most interesting findings of the current study were obtained measuring the newly proposed parameters. We found that the greatest statistical significance comparing the groups of patients and controls had the steepness of cognitive complex (SCC). The other derivatives of amplitudes and latencies of the cognitive complex of AEP also proved their significance.

In our earlier paper (Korostenskaja et al., 2003a) we made a conclusion that a number of newly proposed parameters could be useful in studying various disorders. Most of these parameters have proved their possible usefulness, except the speed of the descending slope (SDS) of the P300 wave. Although it was helpful in differentiating patients with schizophrenia spectrum disorders and healthy controls in the MMN study, in the present study of P300 wave the differences between controls and patients were not significant.

When the patient subgroups where compared with controls only in the subgroup of patients with schizoaffective disorder, we found statistically significant differences. The subgroup of patients with schizophrenia had a larger variability of all measured parameters, so this can be the main cause of the low significance levels. Although some of the patients were receiving medication during the study, there are no consistent data on the effects of antipsychotic medi-

cations on AEPs. Usually a typical antipsychotic medication does not change the P300 amplitudes and latencies in schizophrenia patients (Ford et al., 1994; Umbricht et al., 1998). J. Gallinat et al. (2001) and M. Korostenskaja et al. (2005) could not find changes in the P300 latency and amplitude during treatment of schizophrenia patients with the atypical antipsychotic olanzapine.

The parameters of extrapolation line of the P300 wave showed significant differences when both patient subgroups were compared with each other. This is especially true when the results of analysis of parameters of subtracted waveforms are considered. Such an effect can be explained by the fact that the subtraction process reduces the common sources of variance in the waveforms to the two tasks, narrowing the normative range and increasing the sensitivity (Pratt, 2000). The parameters of the extrapolation line of the subtraction waves of AEP can be helpful in differentiating the subtypes of schizophrenia spectrum disorders, but their significance must be tested in a study with larger numbers of participants.

The psychological and physiological correlates of the novel parameters are not yet fully clear. Additional psychophysiological and neurophysiological studies using the parameters that have shown statistically significant differences between patients and healthy controls are necessary.

Conclusions

1. Patients with schizophrenia spectrum disorders differed from the control group of healthy people in such parameters of auditory evoked potentials (AEP) as the amplitude of P300 wave (A_{P300}), ratio between P300 amplitude and latency, identification time (IT) of target stimuli, steepness of cognitive complex (SCC) and energy of P300 wave (E_{P300}).

2. Such novel parameters as the ratio between P300 amplitude and latency and the steepness of cognitive complex (SCC) showed a more significant difference than did the usually used parameters of P300. These parameters, along with the other significant novel parameters, can be helpful in evaluating disturbances of the cognitive function in schizophrenia spectrum disorders.

3. The new parameters of the digitally subtracted curve of AEP could be helpful in differentiating the subtypes of schizophrenia spectrum disorders.

4. The psychological and physiological correlates of the novel parameters need to be studied additionally by appropriate psychophysiological and neurophysiological methods.

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KLAUSOS SUKELTAS POTENCIALAS: PACIENTŲ, SERGANČIŲ ŠIZOFRENIJOS SPEKTRO SUTRIKIMAIS, NAUJŲ VERTINIMO PARAMETRŲ PAIEŠKA

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Santrauka

Klausos sukelti potencialai (KSP) yra elektroencefalogramos pokyčiai, kuriuos sukelia sensoriniai klausos dirgikliai. Jų registracija leidžia neinvaziniu būdu gauti neurofiziologinės informacijos apie žmogaus galvos smegenų aktyvumą, susijusį su informacijos apdorojimo procesais. Retų reikšmingų klausos dirgiklių (garso tonų) atpažinimas dažnų nereikšmingų dirgiklių eilėje sukelia KSP bangas N2 ir P300 – vadinamąjį kognityvinį kompleksą. Šių bangų parametrai – latencija ir amplitudė – atspindi laiką, reikalingą įvertinti reikšmingą dirgiklį. P300 amplitudė siejama su galvos smegenų neuroninių išteklių paskirstymu, o N2 amplitudė gali būti susijusi su reikšmingų dirgiklių atpažinimo procesais.

Buvo aptikta, kad pacientų, turinčių šizofrenijos spektro sutrikimų, N2 ir P300 bangų amplitudės mažesnės. Tai rodo klausos informacijos apdorojimo procesų sutrikimus sergant šizofrenija. Tačiau klinikinis KSP taikymas susiduria su tam tikromis problemomis (didelis tarpasmeninis rezultatų išsibarstymas), kurioms spręsti nutarėme pasitelkti naujus papildomus KSP kognityvinio komplekso parametrus.

Šio tyrimo tikslas buvo įvertinti naujus P300 bangos parametrus ir palyginti jų patikimumą su įprastiniais P300 bangos parametrais (amplitude ir latencija), tiriant pacientus, turinčius šizofrenijos spektro sutrikimų. Buvo ištirti 56 sveiki asmenys ir 22 pacientai, turintys šizofrenijos spektro sutrikimų. KSP buvo registruojami taikant atsitiktinio įvykio (angl. *odd-ball*) paradigmą – tarp dažnų nereikšmingų dirgiklių atsitiktine tvarka buvo pateikiami retesni reikšmingi dirgikliai, kuriuos tiriamieji turėjo suskaičiuoti. Greta įprastinių parametrų matavome šiuos naujus parametrus: latencijos (L_{P300}) ir amplitudės (A_{P300}) santykį, atpažinimo laiką (IT), kognityvinio komplekso statumą (SCC), P300 bangos energiją, P300 bangos nusileidžiančiosios dalies greitį (SDS) bei greičio parametrus A ir B. Taip pat matavome tuos pačius išskaičiuotos bangos (gaunama iš atsako į nereikšmingus dirgiklius kreivės skaitmeniniu būdu atimant atsako į reikšmingus dirgiklius kreivę) parametrus, žymimus sSDS, sA ir sB. Tyrimo metu paaiškėjo, kad kai kurie naujai pasiūlyti parametrai yra statistiškai patikimesni, lyginant pacientų ir kontrolinę grupes, negu tradiciniai parametrai (amplitudė ir latencija). Daroma išvada, kad siūlomi nauji parametrai gali būti naudingi padedant įvertinti kognityvinių funkcijų pakitimus, esant šizofrenijos spektro sutrikimams, bei atskirti jų potipius. Taip pat skaitmeniniu būdu išskaičiuotos bangos parametrai gali būti naudingesni negu užrašytos tyrimo metu.