EVENT-RELATED POTENTIALS IN DECEPTION DETECTION

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The problem of lie detection has a long history. Main achievements in this field are concerned with registration of peripheral nervous system indicators. Our experiment provides possibility for development of a new lie detection technology, based on neurophysiologic correlates of cognitive processes diagnostics that underlie deception. The experiments were conducted by "Audio-Visual Slider" software (by Medicom MTD), which performed synchronized stimuli presentation and electrophysiological recording.

Keywords: lie detection, nervous system, electroencephalogram, psychophysiology.

The problem of lie detection has a long history. Main achievements in this field are concerned with registration of peripheral nervous system indicators (ECG, PPG, GSR, breathing, blood pressure, EMG). Despite apparent success of detecting deception using polygraph, many researchers still have doubts about polygraph data, because peripheral indicators register the degree of emotional stress rather then cognitive processes. That's why alternative methods are developed, based on brain activity, – fMRI, electroencephalogram (EEG) and event-related potentials (ERP) (Abootalebi, Moradi, & Khalilzadeh, 2009; Allen & Iacono, 1997; Ambach et al., 2010; Farwell & Smith, 2001; Farwell & Donchin, 1991; Mertens & Allen, 2008; Lui & Rosenfeld, 2008; Nose, Murai, & Taira, 2009; Rosenfeld, 2006; Rosenfeld, Rao, Soskins, & Miller, 2004; Rosenfeld et al., 1987; Rosenfeld, Soskins, Bosh, & Ryan, 2004; Vendemia, 2003; Vendemia & Buzan, 2005). Nowadays brain structures involved in deception are localized by means

of non-invasive methods like positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) (Ganis & Kosslyn, 2006; Vendemia, 2003). The data obtained in these studies is a quite contradictory, but still provides an evidence of connection between cognitive processes underlying deception and brain activity.

The analysis of works on ERPs shows that human face is a stimulus to cause dramatic changes in ERP parameters. There is reliable evidence that ERPs for familiar and unfamiliar faces differ significantly (Allison et al., 1999; Bentinm & Deouell, 2000; Caharel et al., 2002; Gauthier et al., 2000; Joyce & Kutas, 2005). But still there are individual differences in distinguishing familiar and unfamiliar faces that affect ERPs. Individual differences are also presented in works on deception detection by event-related potentials (Lui & Rosenfeld, 2008; Rosenfeld, Rao, Soskins, & Miller, 2004).

Spatial analysis of ERPs (of components' scalp distribution) is also a valuable source of information. In works by Rosenfeld et al. (Lui & Rosenfeld, 2008; Rosenfeld, 2006; Rosenfeld, Rao, Soskins, & Miller, 2004; Rosenfeld et al., 1987; Rosenfeld, Soskins, Bosh, & Ryan, 2004) the dynamics of P300 in Fz, Cz and Pz was used to detect deception both on group data and individually.

In this study we used classical amplitude-latency and spatial analysis of ERPs for true and deceptive answers. Unfamiliar and familiar faces were chosen to be used as stimuli, and the participant had to reject knowledge of one face, which was actually familiar to him. So it was a modification of Guilty Knowledge Test with static order of stimuli presentation. Thus, two processes influenced the data: detection of familiar faces and lying that one of them is not familiar. The experimental procedure is designed to control both factors.

Our experiment provides possibility for development of a new lie detection technology, based on neurophysiologic correlates of cognitive processes diagnostics that underlie deception.

Method

Participants

17 healthy subjects participated in the research among which are 7 males and 10 females aged from 19 to 30 (average age is 21), without neurological and ophthalmological disorders.

Equipment

Electroencephalogram (EEG) was registered in acceptance with International 10-20 system (Jasper, 1958) using monopolar design. Channels recorded: Fp1, Fpz, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, Oz, O2 referenced to earlobes A1, A2. EEG was registered with 250 Hz sample rate, frequency band from 0.16 to 30 Hz. Impedance was also registered and did not exceed 10 kOhm. Non-polarizing AgCl electrodes were used. In order to control the participant's functional state, electrocardiogram (ECG), photoplethysmogram (PPG), and galvanic skin response (GSR) were also registered. Artifacts caused by eye movements were detected by means of registering vertical electrooculogram (EOG).

Registration and basic analysis of EEG and EP were performed with hardware and software provided by Medicom-MTD (Russia, www.medicom-mtd.com).

The experiments were conducted by "Audio-Visual Slider" software (by Medicom MTD), which performed synchronized stimuli presentation and electrophysiological recording.

Trial description, subject's instruction and stimuli

The participants were in a darkened room protected from electromagnetic fields, they were half-lying in a comfortable armchair. The stimulation was presented by a monitor Shuttle XP-17, which was positioned 1.2 meters from the participant's eyes. The participant had the following instruction: "Familiar and unfamiliar faces will be presented to you. After you have been shown a face you have to answer a question if this face is familiar to you? Press LEFT button if the face is familiar, and press RIGHT button if the face is unfamiliar. A. Schwarzenegger's face will be presented among familiar faces. Try to cheat the computer and answer, that this face is not familiar to you (press LEFT button)". The participants were instructed orally, and in the written form at the display just before the experiment started.

The stimuli were 52 photographs of familiar faces (FF) and unfamiliar faces (UF). They were presented randomly: random familiar face (not Schwarzenegger's), random unfamiliar face, static test unfamiliar face (UFt), Schwarzenegger's face (Lie). The first two stimuli changed in each chain, and the third and the fourth stimuli were similar in all

chains. Each stimulus was presented for 1000 ms, the interval between the stimuli differed randomly from 900 ms to 1100 ms.

There were 52 photographs grouped into 4 clusters. The first group consisted of 25 *relevant items* – familiar faces. The second group consisted of 25 *irrelevant items* – unfamiliar faces. The third group was presented by *target stimulus* (Schwarzenegger's face) and the fourth group was presented by *static test stimulus* (unfamiliar face). Familiar faces were faces of famous actors and politicians, and unfamiliar faces were borrowed from the Internet photo stores at random choice.

Each of 17 participants took part in the experiment for one time. 25 trials were made, so that stimuli from each group were presented for 25 times in a constant order.

Data analysis

Four event-related potentials, one by each stimulus group, were averaged individually for each of 17 participants. Differences among ERPs were analyzed using ANOVA statistical analysis.

Experimental results

Figure 1 illustrates gross average of ERPs for four groups of stimuli that were discussed earlier (occipital lobe, channel Oz in system 10-20). The configurations of ERPs are similar, and several stable components are registered: P100, N140 and P220. Although stimuli were not normalized by brightness and other physical and configurational parameters, these components do not differ significantly for the considered groups of stimuli. In the waves with higher latency (more than 400 ms) the differences grow, for example, in N600 amplitude.

According to previous research data described in scientific literature, the main differences between ERPs on familiar and unfamiliar faces, as well as on true and deceptive answers, are concerned with P300 component, which has maximal amplitude in central and parietal channels.

Our research (Fig. 2) was aimed to discover two types of differences between ERPs in central channels, e.g. Cz:

1) Among components with 300 – 650 ms latency two positive waves are registered - P340 and P500.

2) When true and deceptive answers are compared, the main difference is in the latency and amplitude of the P160/N240 complex, al-
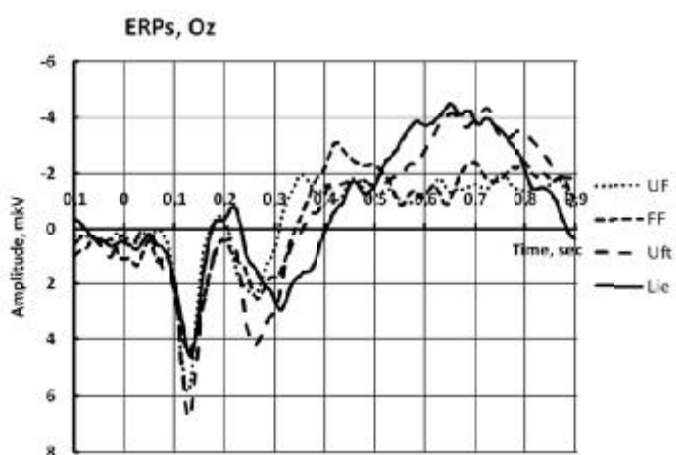
Figure 1. Averaged ERPs for four groups of stimuli
(*occipital lobe, channel Oz in system 10-20*).
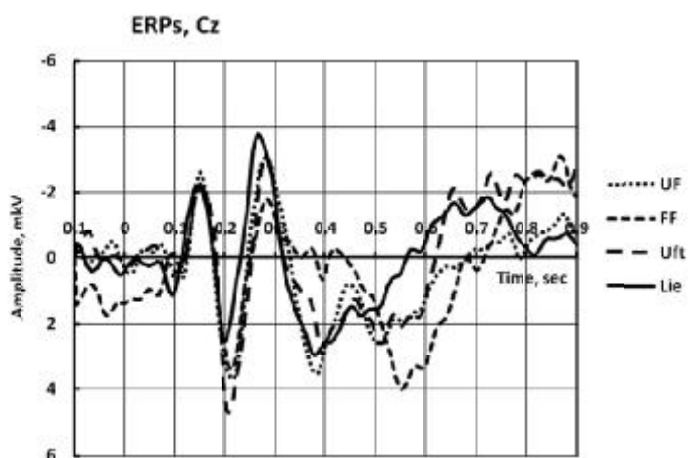For more detailed designation and description see the text

Figure 2. Differences between ERPs on familiar and unfamiliar faces.
For more detailed designation and description see the text.

though these components do not reflect differences between familiar and unfamiliar faces.

Therefore, it is possible to consider that there are two main factors causing differences: deceptive or true answer and familiarity of the face.

These differences are distributed on the scalp. The familiarity of the face affects frontal channels (Fp1, Fz, Fp2, F7, F3, Fz, F4, F8):

Deception (lie) can be found in temporal (T3, T4, T5, T6), central (C3, Cz, C4) and parietal (P3, Pz, P4) channels:

The temporal-parietal area is the most significant. In Figure 3 the difference between deceptive answer and other types of ERPs are shown. They occur in different channels – T3, C3, T5, P3 and the greatest relative difference is in the channel T5.
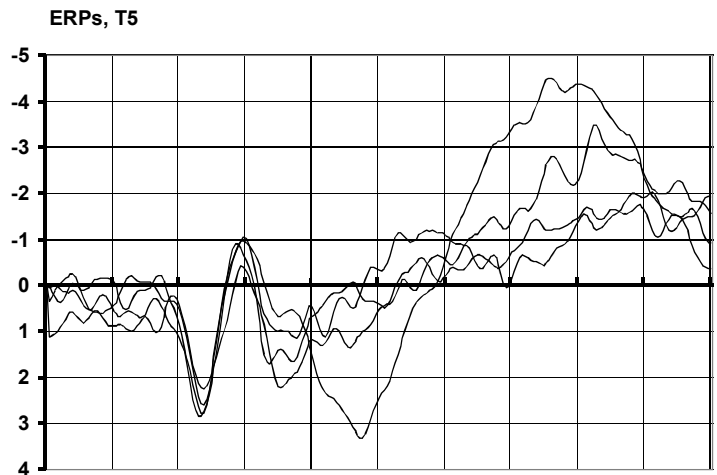

Figure 3. Differences between ERPs registered to Schwarzenegger's face (deceptive answer) and ERPs for other stimuli. For more detailed designation and description see the text

Discussion

1. ERP based detection of deception: grouping data

It is assumed that lie can be uncovered if the following is true:

1. Schwarzenegger's face ERP differs significantly from unfamiliar face ERP (*familiarity factor: we need to know if the test face is really familiar*);

2. ERP Schwarzenegger's face differs significantly from test constant unfamiliar face ERP (*frequency factor: the probabilities of test stimulus presentation and control unfamiliar stimulus must be equal*);

The analysis of averaged ERPs has led to the selection of spatial-temporal fragments, in which the differences were the most fascinating. The criterion lies in the difference between the considered classes of ERPs, which had amplitude more than 1 mkV and lasted for at least 30 ms. These data is shown in *Table 1*.

Table 1

Temporal fragments revised for differences (by channels)

	Fp1	F3	F4	F8	T3	C3	Cz	C4	T4	T5	P3	Pz	P4	T6
Time, msec	220-260	220-260	488-560	488-560	340-400	488-560	488-560	488-560	340-424	268-400	268-384	272-356	264-388	300-384
					488-560					488-560	512-560			488-560

According to Table 1, for T3, T5, P3, T6 channels the differences were found at two fragments. In this text they are indicated as T3(1) and T3(2).

Statistical analysis using ANOVA ($\alpha < 0.05$) was obtained in order to reduce the number of considered fragments (see Table 2).

Table 2

Statistically significant differences

	Fp1	F3	F4	F8	T3	C3	Cz	C4	T4	T5	P3	Pz	P4	T6
Time, msec			488-560		340-400		488-560	488-560	340-424	268-400	268-384	272-356	264-388	300-384
					488-560					488-560	512-560			488-560

2. ERP based detection of deception: individual differences

After analyzing group data we decided to single out individual differences in ERPs. It was assumed that statistical analysis of differences

in wide temporal intervals would lower the influence of the error that was caused by interindividual variations in ERP components latency (compared to the conventional method of analyzing the component amplitude). ERP amplitudes from spatiotemporal fragments listed in Table 2 were taken as dependant variables. ANOVA tests were performed for each of 17 participants for each of 14 selected spatiotemporal fragments.

For the following analysis we have made a classification of individual ERPs:

1. Patterns that coincided with group average pattern – "hits" (deception features, that were discovered in group average, were presented in this spatiotemporal fragment in this participant);
2. Patterns that did not coincide with group average pattern because of lack of statistical significance– "misses" (deception features, that were discovered in group average, were not presented in this spatiotemporal fragment in this participant);
3. Patterns that had configuration incomparable to group average due to large differences in components' amplitudes and latencies – "anomalies".

In the table 3 the percentage of each type is given for all analyzed spatiotemporal fragments.

Table 3

Classification of individual ERPs

	F4	T3	T3(2)	Cz	C4	T4	T5	T5(2)	P3	P3(2)	Pz	P4	T6	T6(2)
% "hits"	59	71	76	59	65	82	88	82	59	65	53	76	65	65
% "misses"	0	18	18	0	6	6	6	0	24	24	24	12	29	29
% "anomalies"	41	12	6	41	29	12	6	18	18	12	24	12	6	6

The percentage of "hits" was interpreted as selectiveness. In this case it is the measure of connection between an ERP difference and deception. If we value selectivity 75% and higher, we will get a reduced set

of spatiotemporal fragments: T5 in 488-560 ms, T4 (340-424), T5 (268-400), T3 (488-560), P4 (264-388).

The analysis of interconnections among these five features showed that each of 17 participants had at least three of them presented. This implies that the information about deception can be taken from this ERP data.

Therefore, if in the selected experimental paradigm a face, that the subject values as unfamiliar, gets positive deviation in ERP compared to control random and static unfamiliar faces, and this is found in at least 3 of this 5 spatiotemporal fragments, it can be implied that the participant's answer about unfamiliarity is deceptive.

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