# ESTIMATION OF THE TIME DELAY BETWEEN PERFORMANCE ERROR AND ITS SUBJECTIVE PERCEPTION DURING DROWSINESS

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The delay is known to exist between the drowsiness beginning as seen by electrophysiological criteria and its perception by the subject. Estimation of the delay is important, and new ways to do it are looked for.

## Aim of the work:

To look for objective criteria of the moment of the subject's perception of the error and to estimate delay in perception.

## Suggestion:

To identify the moment of error in performance of psychomotoric test (button pressing - BP) as an indication of drowsiness and time of electrodermal reaction (EDR) to estimate the moment of subjective perception of the error.

## EXPERIMENTAL

**EDA:** Three independent measures of skin resistance with external voltage source (0.9 v). Dry electrodes; two pairs of rings on fingers and the bracelet on wrist with area 1 $cm^2$.

### Other parameters:

- 2 monopolar EOG (horizontal and vertical) with left mastoid reference,
- monopolar EEG ($C_z$), right mastoid reference,
- ECG (nonstandard – left arm - left mastoid),
- test performance - the voltage of the diod due to pressing.

Registration: Polygraph MACLAB 8E, with Macintosh computer. Sampling rate 100 Hz, with 12 bit ADC. The amplifier bandwidths for EOG, EKG and one of EDA channels -0.7-20 Hz, for EEG - 0.7-50 Hz., for two EDA channels – high frequency filters (upper limit 20 Hz).

## SUBJECTS

64 subjects (aged 18-60) with good EEG alpha-activity without sleep deprivation participated in 280 experiments. They were activated at the beginning (by mental or emotional stress - unpleasant talk or sounds, calculations or computer games, when unsuccessful). After activation the subject sat in comfortable posture with closed eyes and performed a psychomotoric test that involved counting from 1 to 10 while pressing a button, then counting from 1 to 5 without pressing and so on. Experiments were started in the afternoon (17-20) and lasted 40 min.

Two experiment modifications:

1 type - orientation on best performance; experimenter observed the subjects and activated them after first error or first signs of drowsiness;

2 type - orientation on drowsiness; experimenter left the subject alone and wakened him after 15-20 min. independent on performance.

## Experimental shedule

1 - eyes open, activation (count, computer games, unsuccessful) without button pressing (BP) (1-5 min).
2 - eyes closed, without BP (1-5 min).
3 - BP with closed eyes (10-20 min).
4 - activation with opened eyes, reports (1-5 min).
5 - BP with closed eyes (10-20 min).
6 – reports.

ECG and EEG analysis – using internal software of Polygraph, on Macintosh computer.

EDR identification - software developed by us based on the shape of time dependence of conductance and its derivative by time.

Statistical treatment of the results: software STATISTICA 6 on Pentium.

## Results

Errors in performance occurred about 5-10 min from test beginning. They were estimated by:

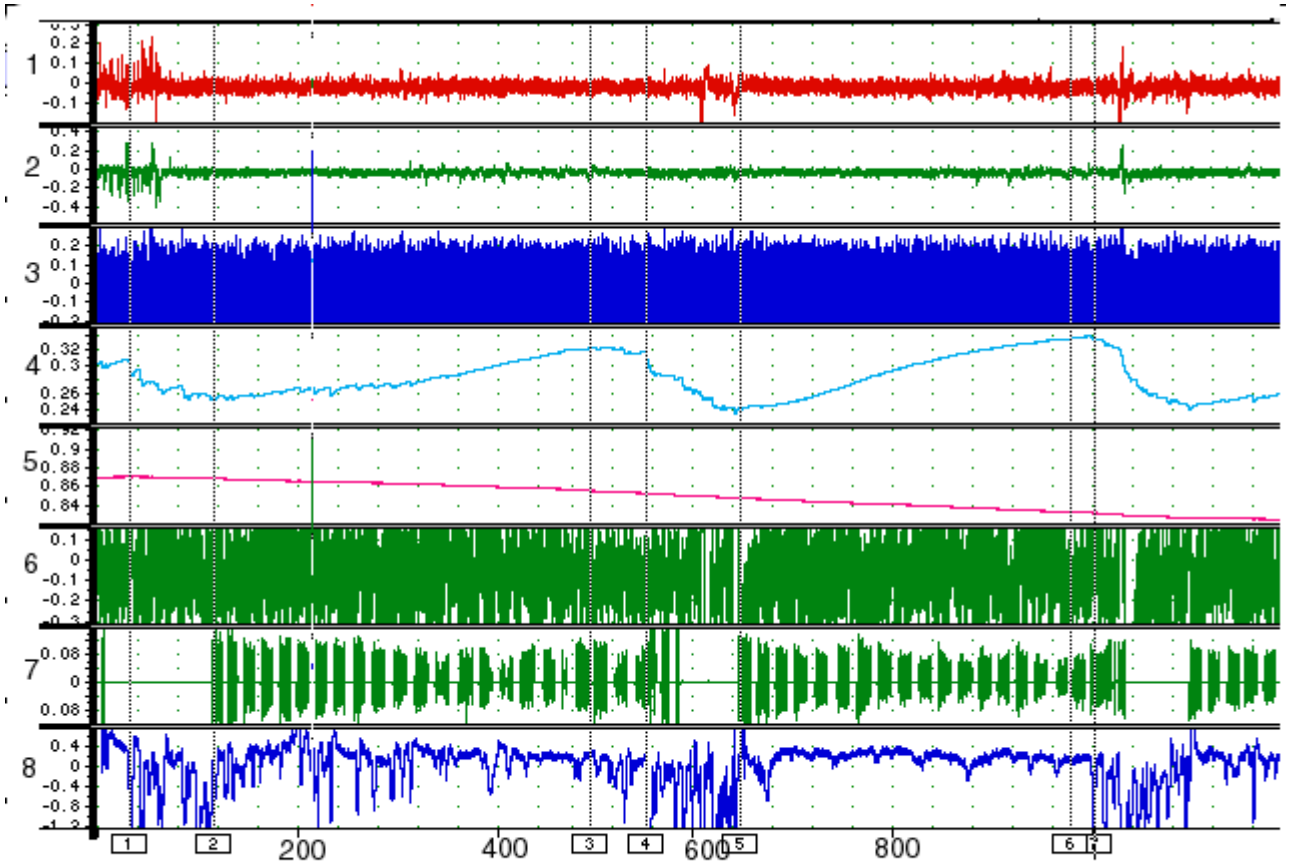
- parameters of performance - failures in counting (wrong number of pressings and/or wrong interval between them);
- electrophysiological parameters changes (EEG, EOG, ECG);
- self-estimation on interrogation.

## Errors classification:

1) accidental - electrophysiological para-meters unchanged, self-estimation- alert.
2) reversible - performance and electrophysiological parameters change temporally, then return, self-estimation - "not drowsy, but distracted".
3) irreversible - series of errors after the first ones; parameters suggest drowsiness, then first sleep stages. Self estimation – drowsy or asleep.

**Fig.1.**

Example of polygraphic registration in conditions of experiment of type 1.




Chan

nels: 1- EOG horizontal, 2-EOG vertical, 3-ECG, 4-EDA, fingers, 5-same, wrist, 6- EEG ($C_z$), 7-diod voltage due to pressing, 8-EDR, phasic (filtered).

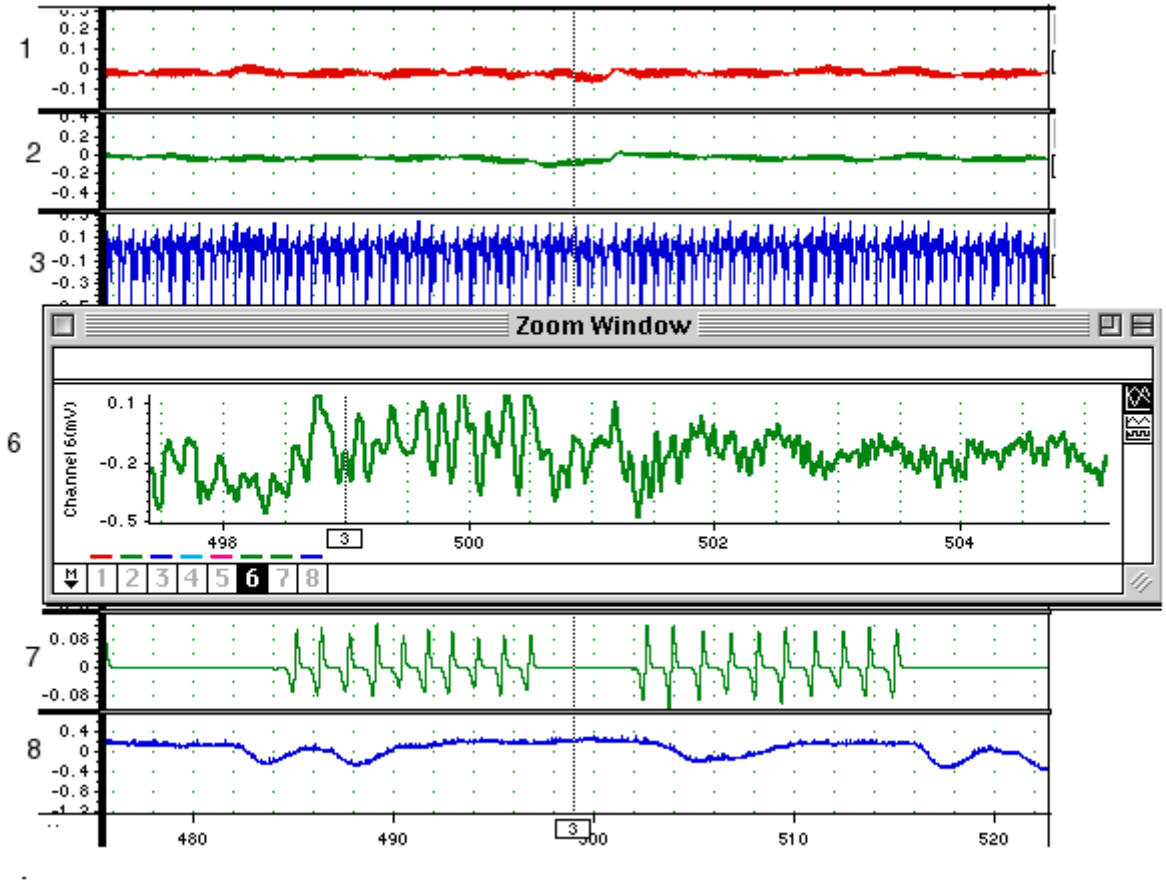
Horizontal axis –time (seconds), vertical –4,5,7 –V, others –mV.

Three activations are shown: 1-2, 4-5, 7.

Activations follow reversible errors 3,6. Both errors are followed by EDR.

**Fig. 1b.**

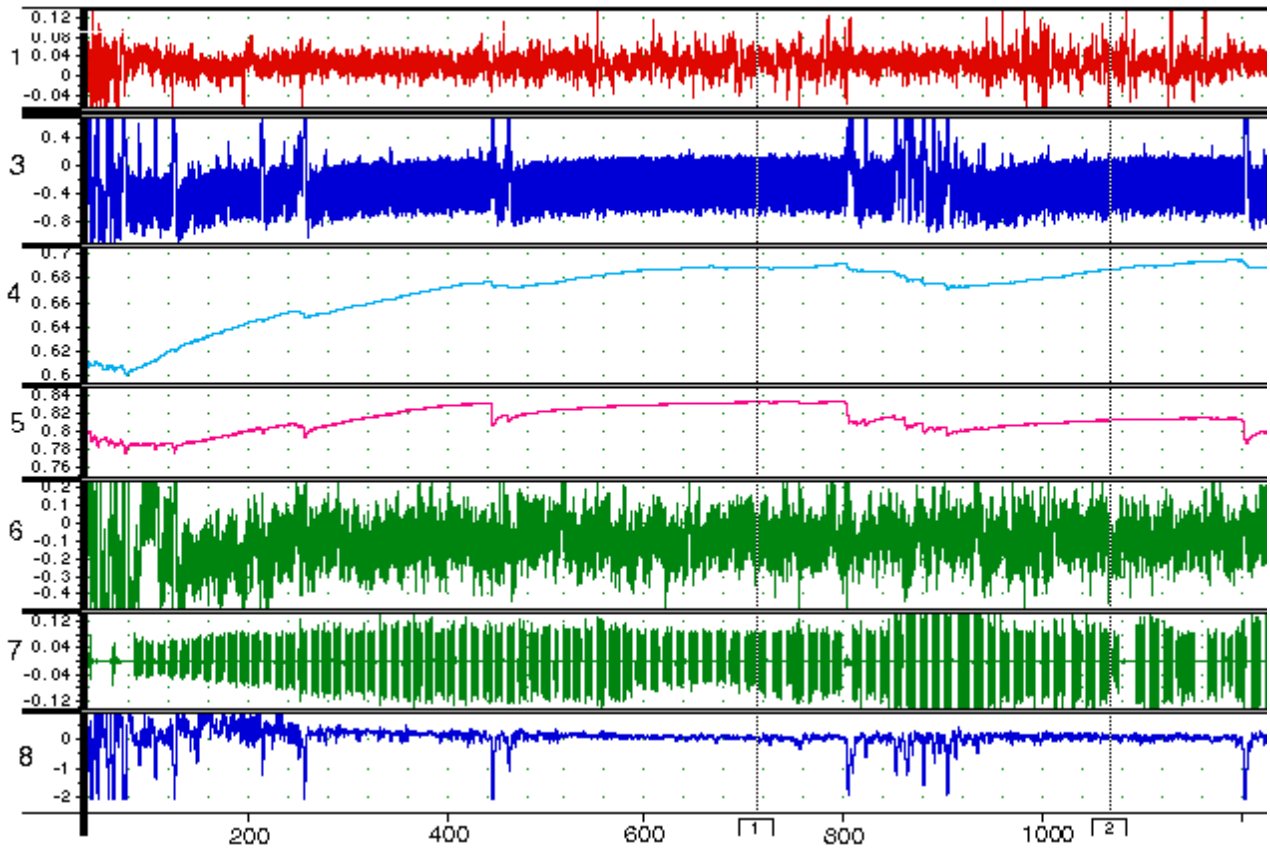
Example of polygraphic registration near reversible error 3, extended by time.




Channel 1 – EOG horizontal, 2-EOG vertical, 3-ECG, 6-EEG in Zoom window, 7-button pressing, 8- EDR (phasic).

**Fig.2.**

Example of polygraphic registration in experiment of type 2, with errors of both types.

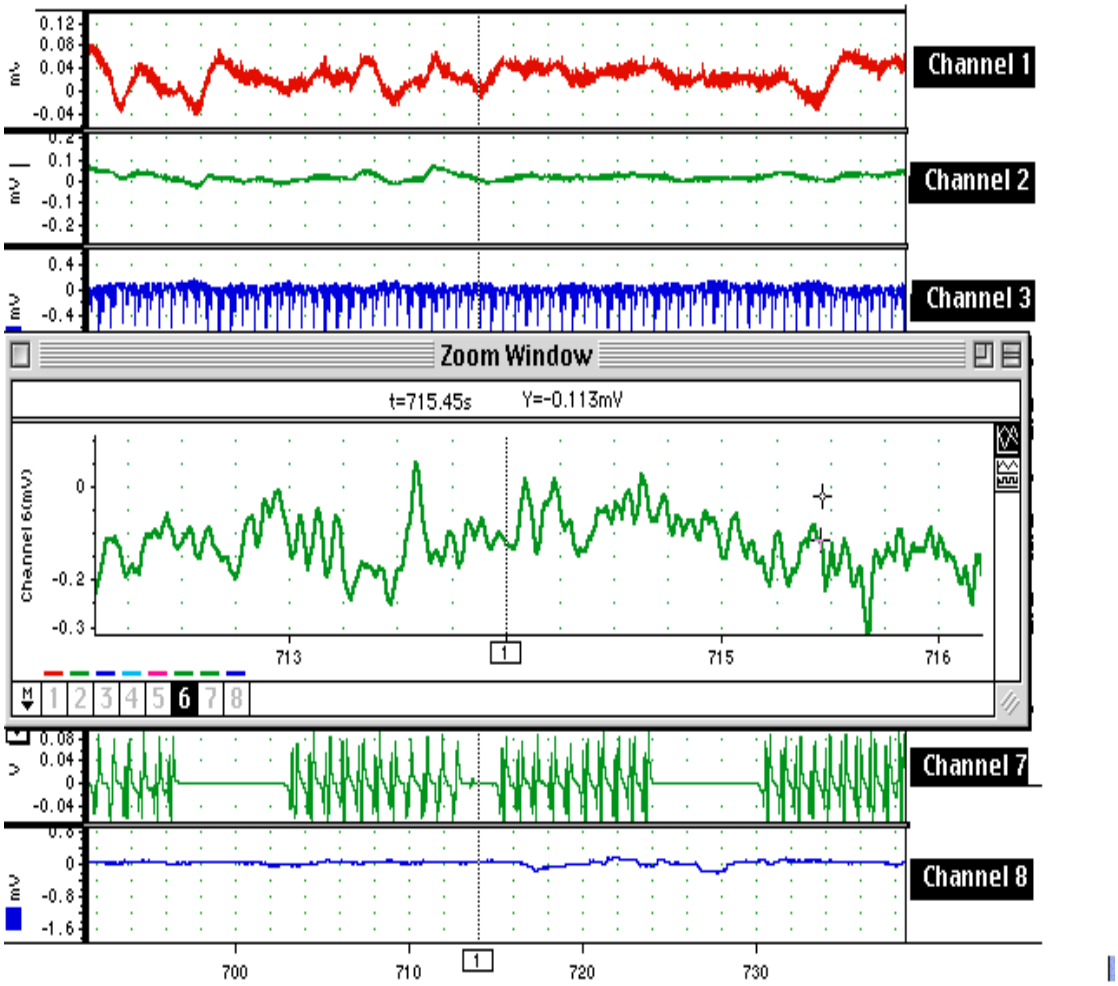



Channels: as in Fig. 1

Errors: reversible (mark1), irreversible (mark2).

**Fig.2b**

Example of polygraphic registration near reversible error, extended by




time.

Channel: 1– EOG horizontal, 2- EOG vertical, 3- ECG, 6- EEG in Zoom window, 7- button pressing, 8- EDR (phasic).

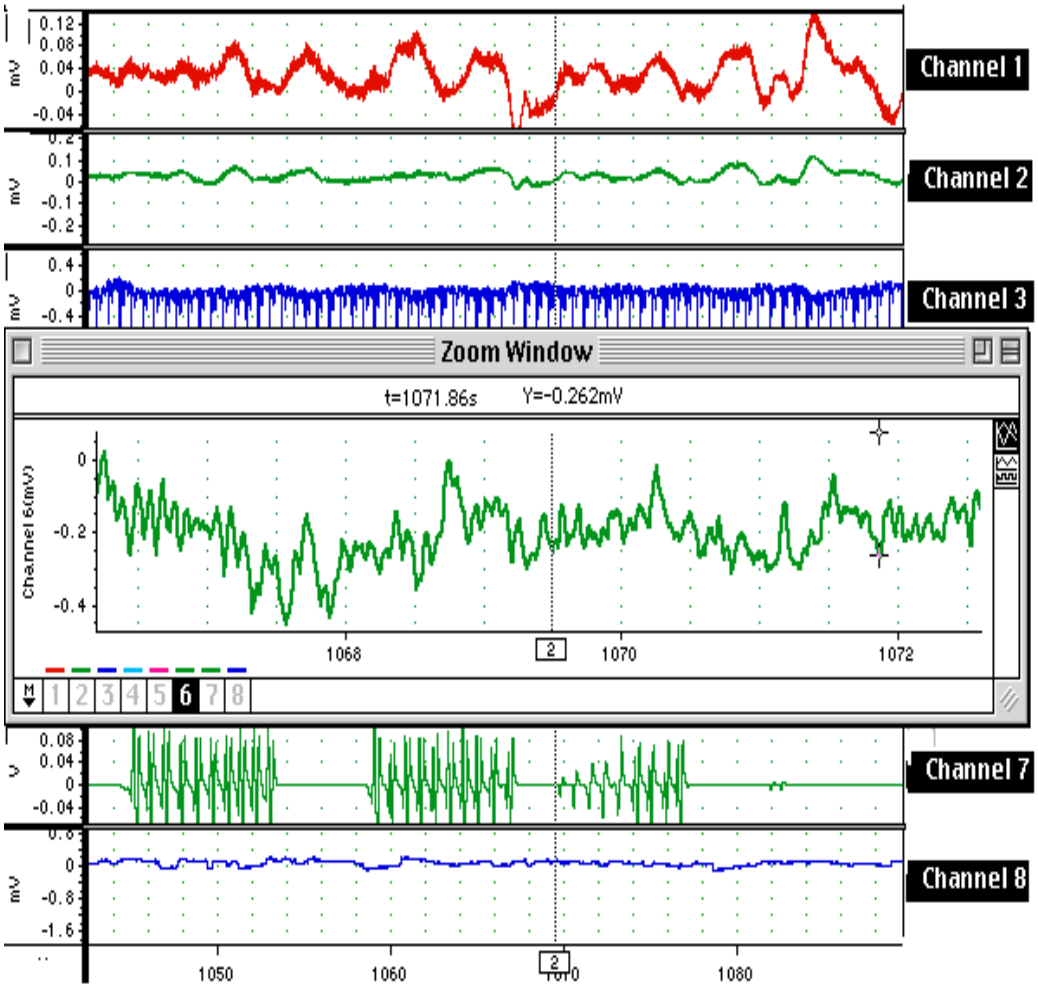
Amplitude of horizontal EOG increased, slow EEG component (theta/delta waves) is seen near the marker (before and after- mostly alpha-activity). These changes in EEG, EOG are temporal.

On drowsiness beginning, first error appears, accompanied by several slow EEG waves. Then full arousal may occur, seen by correct performance and slow EEG waves disappearance (reversible error).

After irreversible error, EDR are absent, high amplitude horizontal EOG, slow EEG components and ECG changes preserve.

**Fig.2c**

Example of polygraphic registration near irreversible error, extended by time.




Channels as in Fig.2b.

EDR almost always appears immediately after the reversible error, see Fig.1,2. The interval between error and EDR is of the same order as the one between the emotional stimuli and induced EDR.

For consideration of error perception, only reversible errors should be taken into account.

In experiments of the first type, when the subjects knew that they will be activated with the first error, most first non-accidental errors were reversible.

In the second series, with orientation to drowsiness, reversible errors are more common to subjects that performed most carefully, as seen by few accidental errors.

In 54 % of all experiments, (almost always in experiments of the first type) first errors are followed by 1-2 EDR. Simultaneously with EDR, but after the error, movements of the subjects are registered. Then performance and electrophysiological parameters return to those before error. Example is seen on **Fig. 2.**

Intervals between previous EDR and error (Int1), between error and next EDR (Int) and that including error (Int0=Int1+Int) were measured.

**Fig.3** shows distribution of Int, **Fig.4** - distribution of ratios Int/Int0.

**Fig.3**

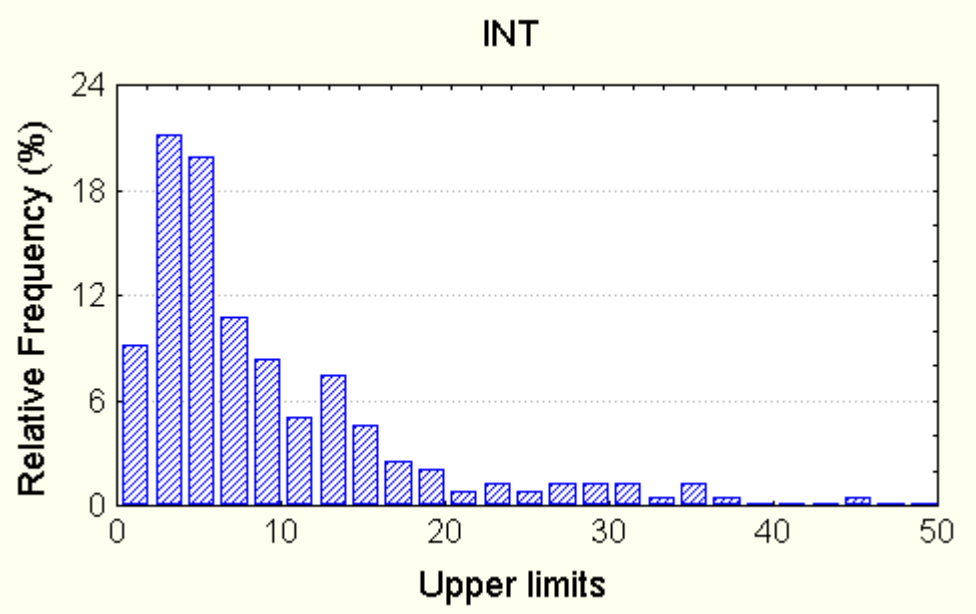
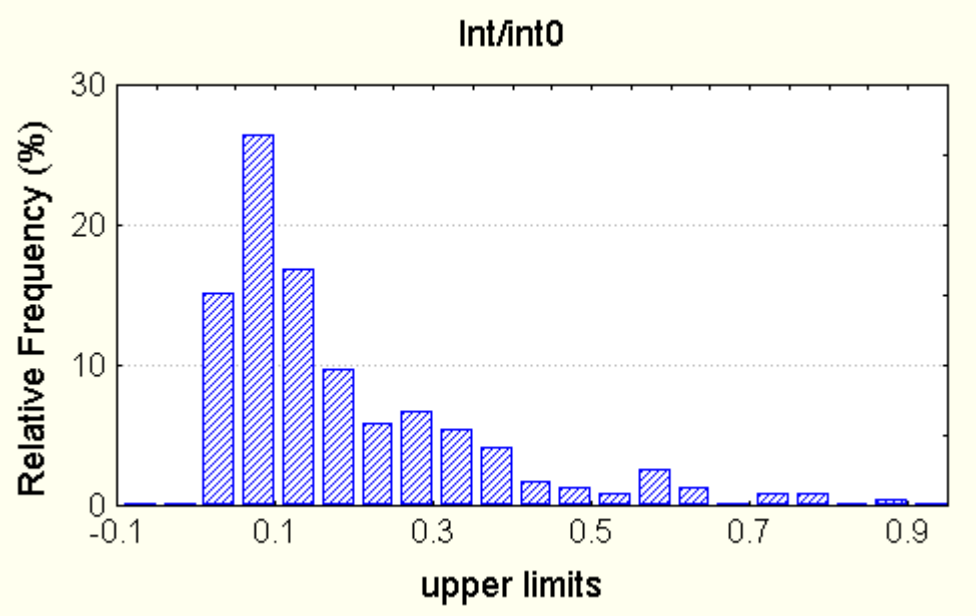
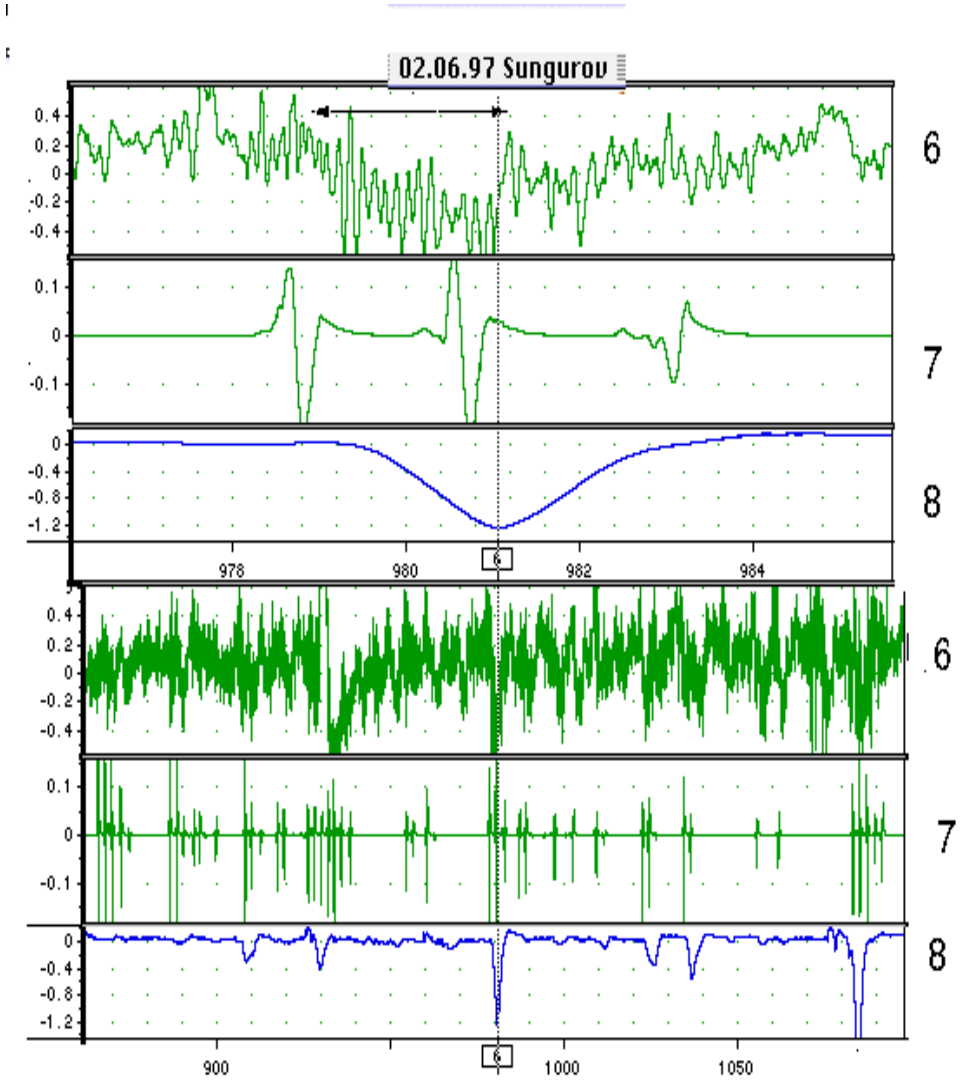



**Fig.4.**




After irreversible error, EDR not accompanied by arousal occur only rarely. If they are registered during drowsiness and first sleep stage, they occur simultaneously with appearance of alpha-activity in EEG and several button pressing, if they were absent before, see Fig. 5.

**Fig.5.**




Here, only three channels (same as in Fig.1,2) are shown in two time scales. In the lower part, several EDR are seen on Channel 8; above them, several button pressing are registered on Channel 7. In the upper part, temporal alpha-activation is shown by arrow just before EDR.

## Discussion.

The connection of EDR after error with the latter is suggested by the fact that the interval between error and this EDR is statistically significantly less than mean interval between EDR for the same subject (t-test for dependent variables).

It could be supposed that there exists causal-investigatory connection between error and EDR - that EDR is induced by error. In support of it is the fact that Int doesn't exceed 5 s in 40% of cases, the time that corresponds to the time delay between stimuli and response (EDR). More prolonged intervals are due to the fact that the connection is not direct: error - its perception - negative emotion - EDR.

In favor of the supposition that EDR are connected with perception of error are the results of questioning of the subjects activated just after the error (experiments of the first series). The affirmation of the suggestion that perception is connected with unpleasant emotion and the desire to correct it is the fact that EDR after error were seen more frequently in experiments of the first series than the second. Indeed, in the first series the orientation was on correct performance, and the subject knew that error will be noticed and will cause activation, which is unpleasant. Additional affirmation is the fact that in the second series, when activation was independent of errors, EDR after errors were seen mostly for the subjects that performed carefully, and error could be supposed to be unpleasant by itself.

It was already mentioned that EDR accompanies reversible errors only in 54% of cases. There could be several reasons for it.

1) EDR disappeared during relaxation more than 3 min. before first error. In this case, EDR reappear no sooner than after 2 minutes of activation, so they could not emerge due to perception of an error. .

2) the error is not noticed - it applies to small errors,

3) the error is not realized. In the last case EDR frequently appear after next error.

If EDR is indeed connected to error perception, the interval between error and next EDR could be taken as estimation of time delay of the said perception, in case when the interval is significantly less than mean interval. According to Fig.6, this time varies from 2 to about 30 sec.

## Summary

The appearance of performance errors were shown to be accompanied by electrophysiological changes typical for drowsiness. The renewal of proper performance in more than 50% cases is accompanied by EDR appearance, alpha-activation in EEG and the subject’s reports of sudden perception of the error. Rather often the electrophysiological arousal after error was accompanied by subject's movements or activation posture changes.

The time interval between error and next EDR is significantly less than the interval between previous EDR and error, suggesting the connection between error and EDR, possibly of causal-investigatory nature. The arguments for the suggestion that EDR appearance is connected to the error perception and is a component of orienting reflex, connected with emotional regulation of consciousness and arousal level, are given.