The peculiarities of electrodermal reactions accompanying the changes of alertness in humans

Dementienko V.V., Dorokhov V.B., Koreneva L.G., Markov A.G., Shakhnarovitch V.M.

Lately the use of EDA in psychophysiology decreased considerably as there are doubts of the results reproducibility. On any matter one can find in the references the opposite opinions.

Examples of cases of contradictions:

- the existence of gender differences in EDA
- the frequencies and nature of "EDR-lability" and "EDR-stability".

The aim of the work:

- to look into the nature of contradictions mentioned;
- -to suggest the ways of reproducibility increase.

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 diode 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: 108 volunteers aged from 16 to 69 with good alpha-activity without sleep deprivation, sat in comfortable posture. Activation at the beginning (mental or emotional stress - unpleasant talk or sounds, calculations or computer games, when unsuccessful).

Two kinds of experiments:

1) Orientation on maintaining awake and active - open eyes in illuminated room, allowance to talk with one another or with experimenter, read books, play computer games successively. (43 subjects, 20 men and 23 women).
2) Orientation on decrease of arousal level up to going asleep. Closed eyes, dark room, performance of monotonous psychomotoric test (pressing the button of piezodiode while counting from 1 to 10, then counting to 5 without pressing the button, and so on). (64 subjects, 29 men and 35 women).

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

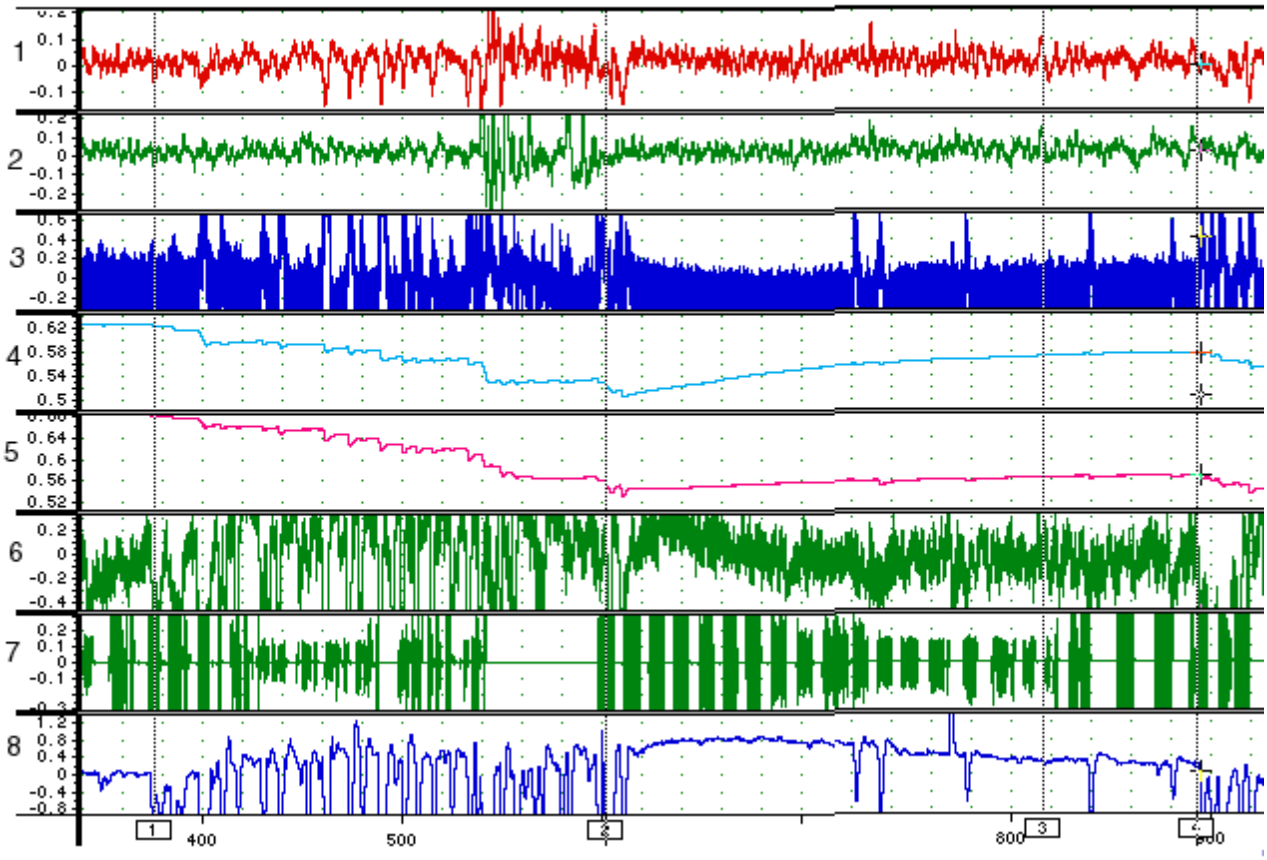
EDA parameter chosen: interval between two successive EDR.

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

Statistical treatment of the results: software STATISTICA 5 for Windows.

Results

Fig.1.

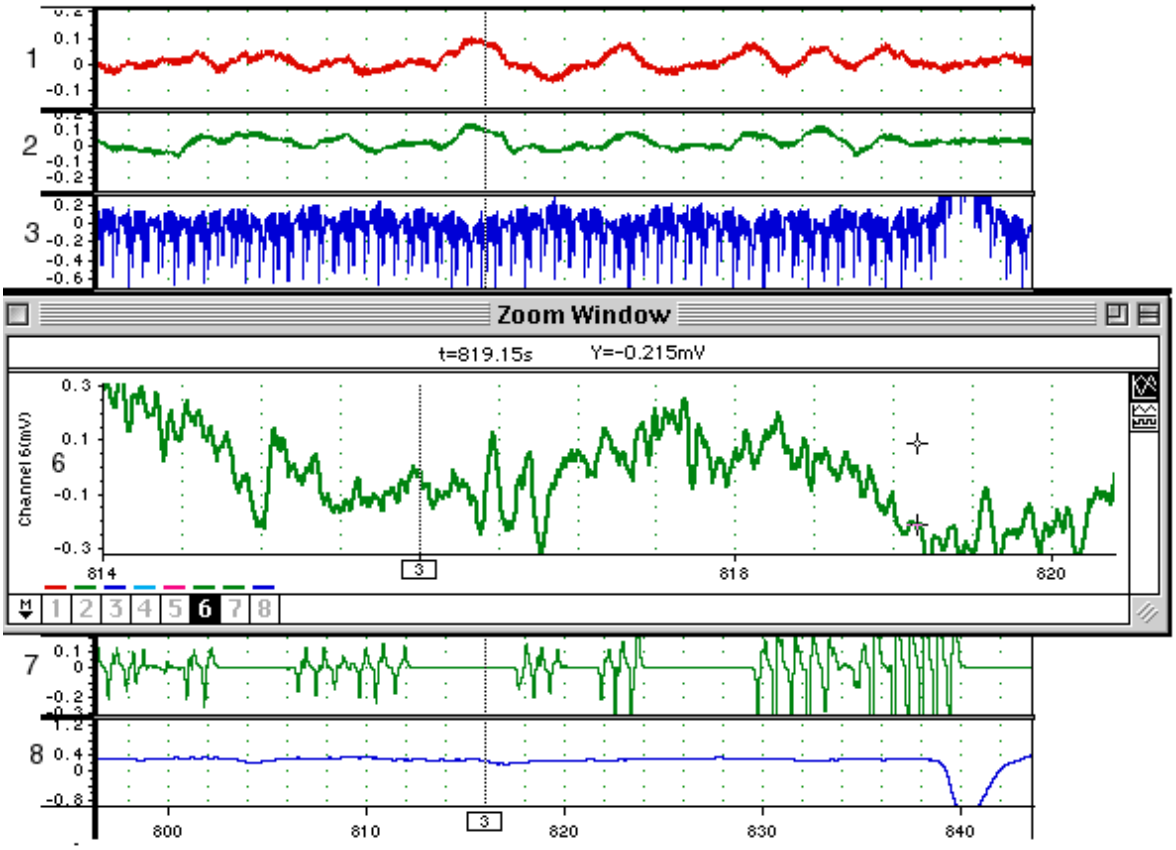


Example of polygraphyc registration.

Channels: 1- EOG horizontal, 2-EOG vertical, 3-ECG, 4-EDA, fingers, 5-same, wrist, 6- EEG, 7-diod voltage due to pressing, 8-EDR, phasic (filtered).
Horizontal axis –time (seconds), vertical –4,5,7 –v, others –mv.
Between marks 1,2 – activation (computer game), 2-4- relaxation, from 4 – second activation. Mark 3 – error in performance.

Fig.1b

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

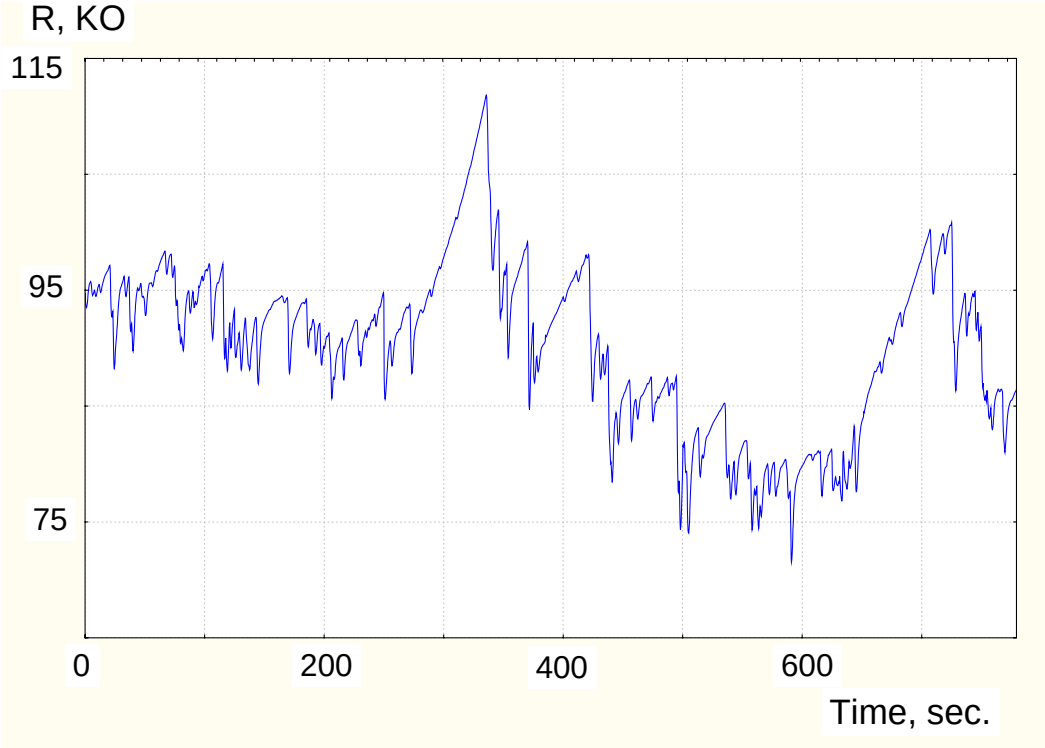


Channels 1-3, 7,8 as in Fig.1, 6-EEG in Zoom window.

Amplitude of horizontal EOG increased, slow EEG component is seen near the marker (before and after- mostly alpha-activity. EDR is seen after the error on Channel 8.

Fig.2.

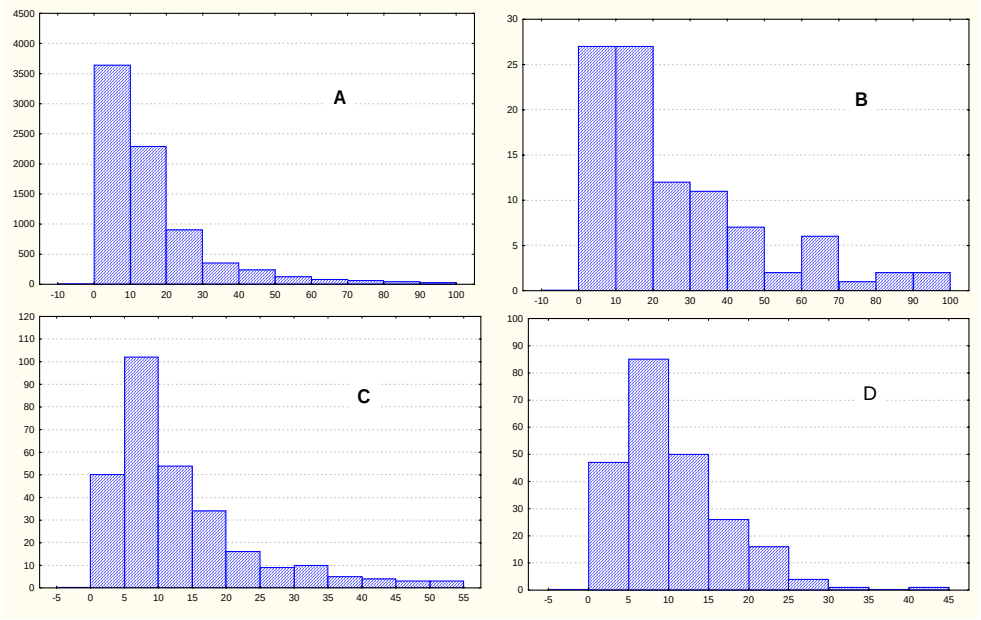
Example of the resistance changes in conditions of quiet arousal.



Multiple EDR are seen as peaks of swift resistance decrease. Between groups of EDR, resistance increases. The longest interval between EDR is seen around 300 sec. and is approximately 90 sec.

Fig.3.

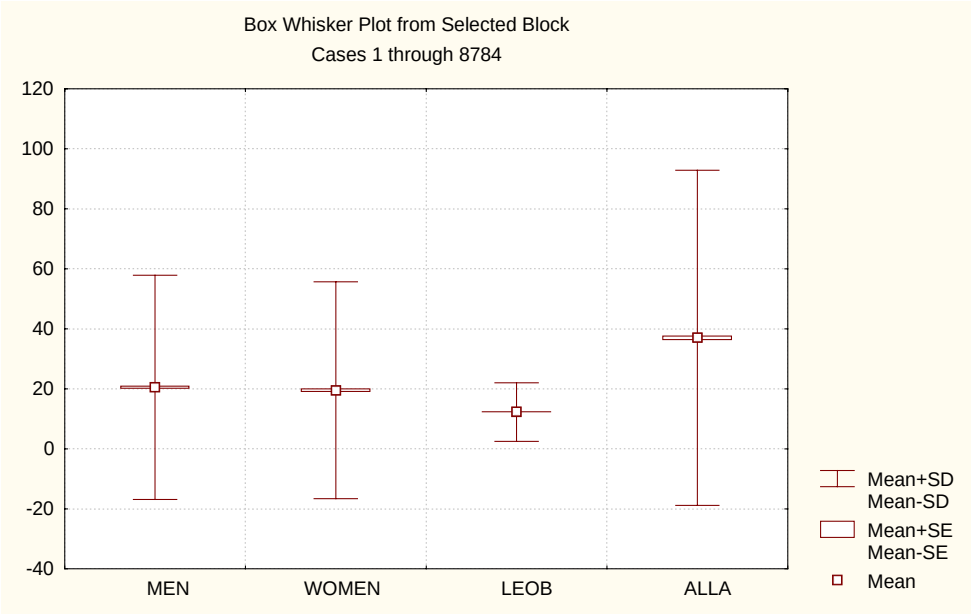
Histograms of interval distributions in condition of quiet wakefulness.



Interval distributions (horizontal axis – boundaries, vertical – number of observations of intervals between boundaries); A - distribution found in about 400 experiments with 45 subjects in the condition mentioned (N=8780); B,D- distributions for two persons (women) for whom the differences in parameter are most pronounced (B maximal stability N=265, mean 37, D- maximal lability, N=533, mean 12), . Differences between these women are statistically significant ($p<0.01$). C – labile man. Heterohenity of parameter is obvious.

Fig.4.

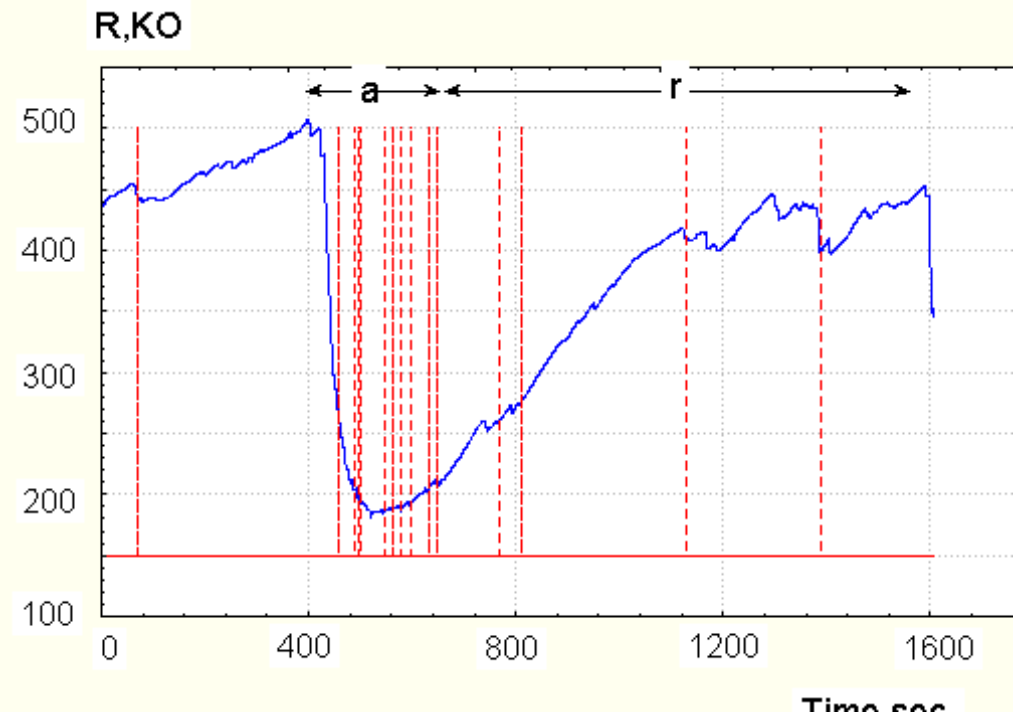
Examples of mean values and standard deviations in interval distributions in conditions of quiet wakefulness.



Standard deviations (boxes, mean values in the middle) and standard errors (whiskers).
1-men (N=3400, m=19.5), 2-women (N=5380, m=20.5), 3,4 – same women as on previous figure. There are no significant differences in parameter for men and women (p=0.2).

Fig.5.

Example of finger resistance changes during activation-drowsiness cycle (second type experiment, monotonous work with closed eyes).



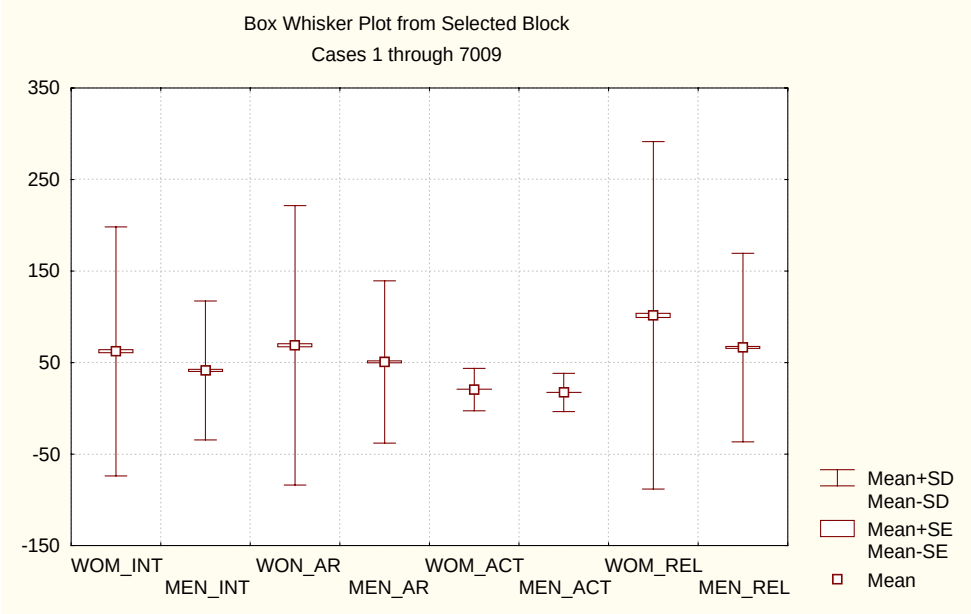
Horizontal axis- time (seconds), vertical – resistance in KOm. Vertical lines (red dotted) show the positions of EDR found by the software. Arrows above a- activation (from eyes opening to their closing and test beginning), **r** relaxation (alertness decrease from performance beginning).

The subject is "EDA-stable", the intervals increase immediately after performance beginning.

Usually the resistance begins to increase within 1-2 minutes after beginning of monotonous work. The intervals between EDR begin to increase and exceed 5 min. before sleep occurs, as seen by EEG, EOG and ECG. Sometimes first sleep stage may occur in 15 min.

Fig. 6.

Mean values and standard deviations for men and women during activation-relaxation cycles.



Standard deviations (boxes, mean values in the middle) and standard errors (whiskers).

First two columns are data for all 64 subjects, activation and relaxation periods are not separated: first -35 women (N=3430, m=62), then – 29 men (N=6980, m=41).

Other data are for 14 subjects for whom periods of activation and relaxation were separated. 3,4 **(AR)** are data for both activation and relaxation: 7 women (N=2010, m=68), then 7 men (N=3350, m=50);

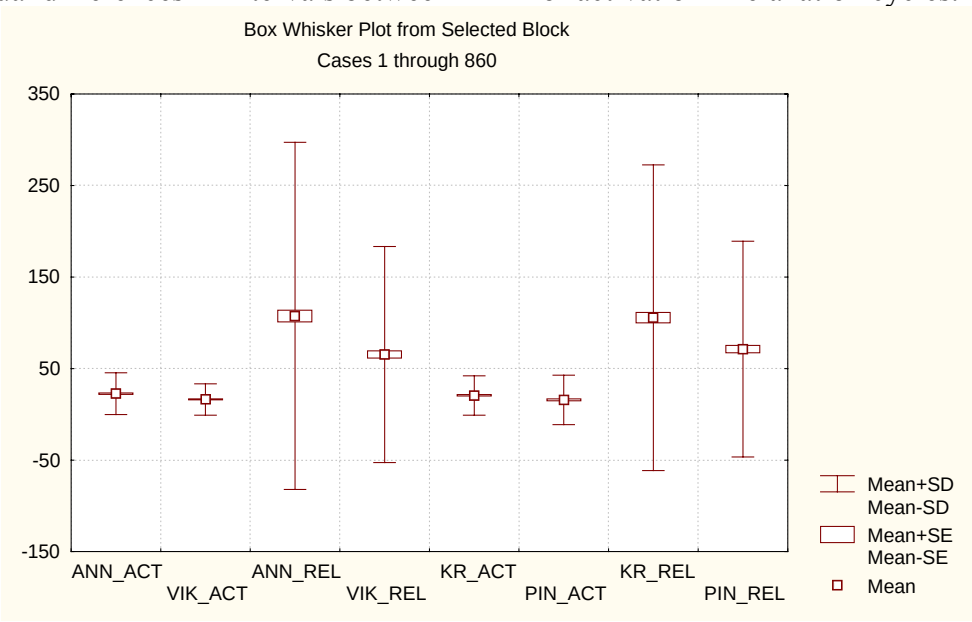
5,6 **(ACT)** are data for activation: women-(N=810, m=20), then men - (N=1080, m=17);

7,8 **(REL)** are data for relaxation: women (N =1200, m=100), then men (N=2270, m=66).

All gender differences are statistically significant (1,2 - $p < 0.000001$, 3,4 - $p < 0.000001$, 5,6 - $p = 0.002$, 7,8 - $p < 0.000001$).

Fig.7.

Individual differences in intervals between EDR for activation – relaxation cycles.



Designations are the same as in Fig.6.

1,2 two women, activation (N1=209, m1=20; N2=173, m2=17, differences significant, p=0.003). 3,4 same women, relaxation (N1=160, m1=107, N2=480, m2=65, p=0.0009). 5,6 two men, activation (N1=100, m1=20, N2=274, m2=18, differences unsignificant, p=0.14); 7,8 – same men, relaxation (N1=139, m1=105, N2=629, m2=71, differences significant, p=0.004).

Discussion

As could be seen from Fig. 6, gender differences are slight during activation and pronounced - during transition to drowsiness. Slight, but statistically significant individual differences during activation are seen only between 20% of women and not seen for men, see Fig.7. During transition to drowsiness individual differences are quite pronounced.

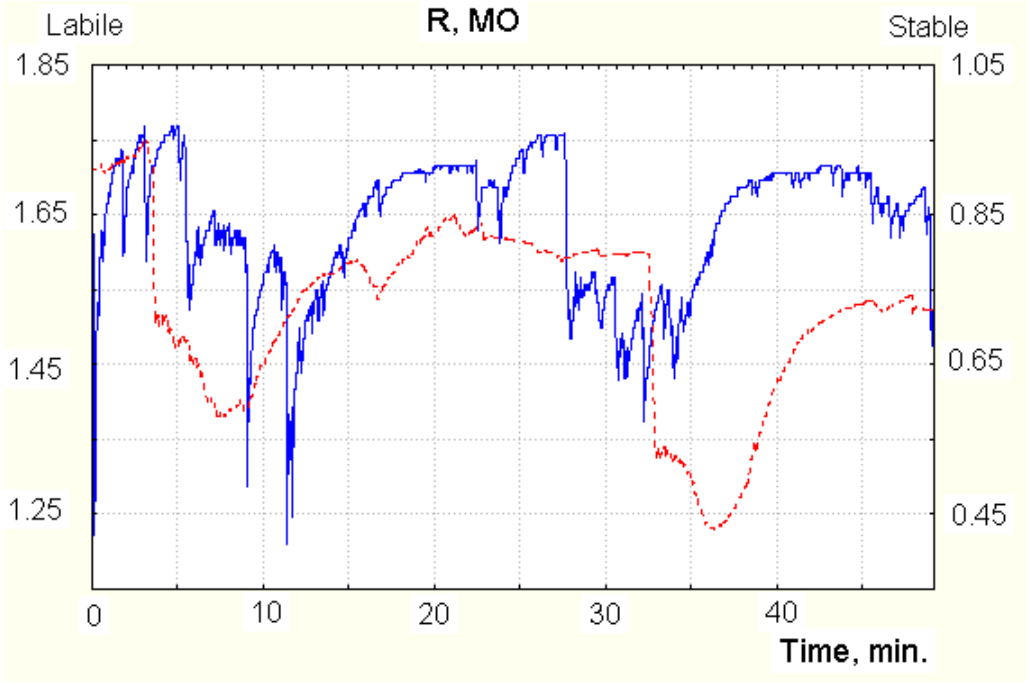
So, gender, as well as individual differences in EDR frequency could be attributed to differences in relaxation. During activation, differences between "stable" and "labile" persons are not seen in most cases. For example, in Fig. 7 the results for most labile person are compared with those for most stable, and there are no significant differences during activation.

Therefore, when such differences are looked for, any result may be obtained if the times of activation and relaxation are not strictly determined.

The rate of relaxation has individual differences that could be considered "stability" or "lability" level. Example of resistance changes for "stable" and "labile" persons is seen in Fig.8.

Fig 8.

Resistance changes for labile (solid line, left scale) and stable (dotted, right) persons.



Most differences are seen for relaxation periods (resistance increase), where for labile person multiple EDR could be seen, while for stable person there are none.

The lability parameter could change from experiment to experiment. The example of change from lability to stability for the same person could be seen on Fig. 9,10.

Fig 9

Resistance changes in activation-relaxation cycles for EDA-labile person. Vertical lines (dotted) sign the positions of EDR as found by the software.

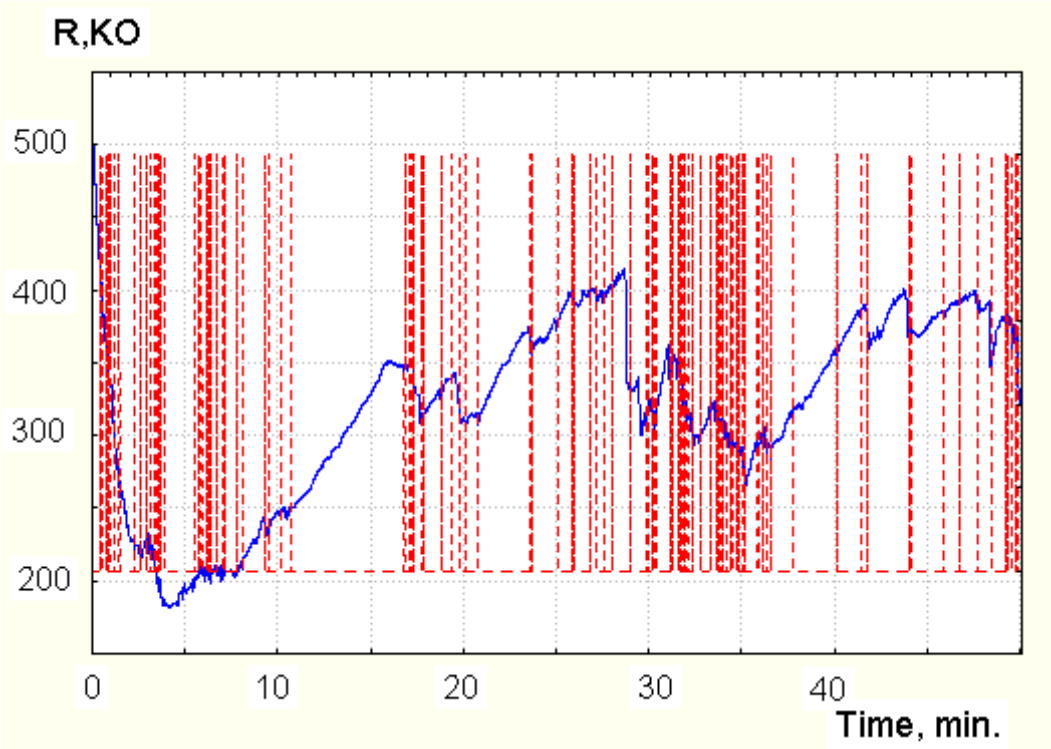
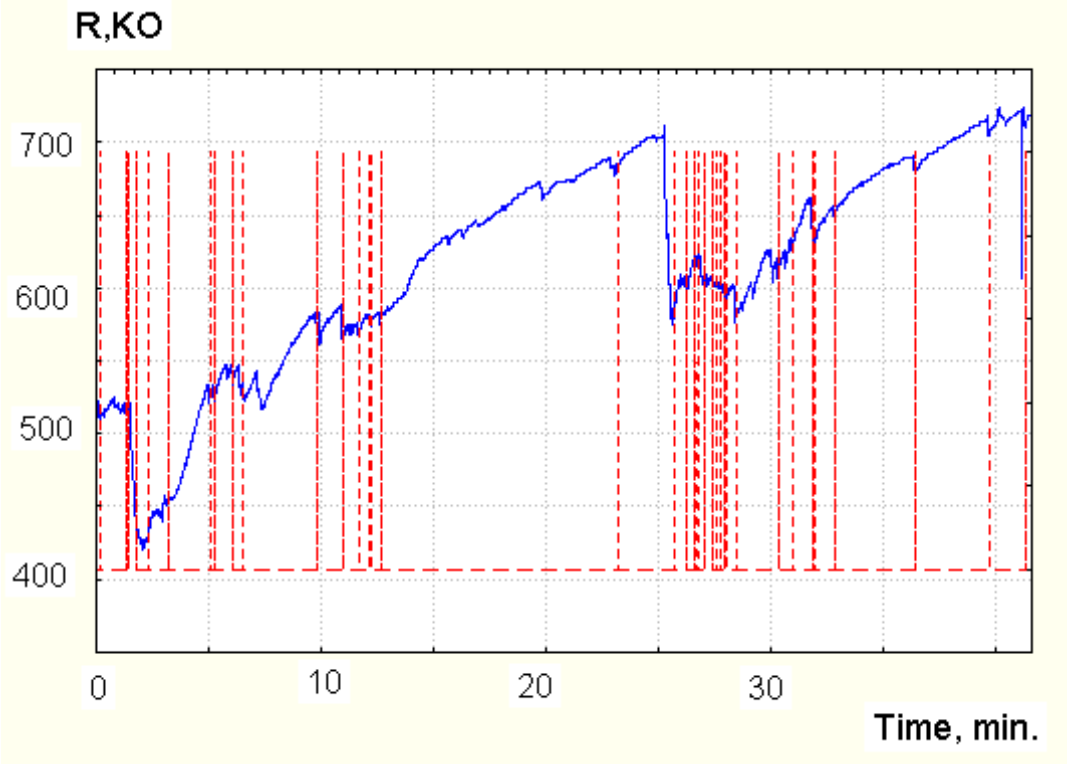


Fig. 10.

Resistance changes in activation-relaxation cycles for the same person in EDA-stable condition.



The condition is perhaps due to original “sleepiness” as seen by EEG. . Vertical lines signing the EDR positions are considerably less frequent.

So to estimate "lability level", several experiments must be made.

Suggestion: to control arousal level.

Way to increase and stabilize the high level: mental stress - arithmetic and computer games when unsuccessful.

Way to decrease the level: monotonous psychomotoric work with closed eyes.

Therefore the reproducibility could possibly be increased if at the beginning of each experiment (may be before the registration) the subjects are activated. Even better results could be obtained if several activations and relaxations are registered.