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The problem of detection of micro-sleep on human operator

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Abstract

This paper discusses the decrease of attention of a human operator in course of his long term interaction with technical systems. Primarily it concerns possible creation of micro-sleep and its detection by means of electroencephalography (EEG) followed by evaluation using mathematical methods. Secondly this paper deals with preventing attention decrease by means of biofeedback or warnings by the technical system to the human operator evaluated by means of „fail safe" principles.

1. Introduction

Problems of reliable interaction between artificial systems and human beings is still not satisfactorily solved. Implementation of new technologies with elements of intelligence decreases probability of defects and increases the service life of such devices, but at the same time it is more demanding on the reliability of human operators.

Operators who work with complex and efficient artificial systems such as transport systems (aircraft, train expresses, trucks, ships), extensive power station systems, security and defensive systems and others, have to make fast and correct decisions with maintaining maximum focus and concentration on the specific task. These complex, demanding tasks on human operators are jointed by many other internal and external factors such as length of working hours, mental and physical state, extreme climatic conditions, quality of working environment, but also monotonous scenes or view which operator must watch.

The present focus of our research is to recognize decrease of attention and thereby decrease of reaction on created stimulation. With almost constant scene or view seen by operator and optional personal indisposition can result in significant decrease of his attention, which can possibly lead into micro-sleep (momentary drowsiness). This state of human brain is very dangerous and might lead to huge material and financial damages but more importantly to losses of human lives. Like one of instance presentation disaster from May year 1999, which with state in Tauern tunnel, where fall attention driver lorry result death 12 human lives and general economic damage of 9 billon shilling

2. Material and Methods

To be able to find the decrease in the operator's attention while interacting with systems we have to monitor most significant parameters, which will unambiguously identify decrease of attention and possible accession of micro-sleep. The most significant parameters are:

electric activity of brain; frequency of breath; heart beat frequency; eyes movement of (or lid movement if needed) and others.

Attention of a human operator constantly fluctuates. These changes can be considerable in course of the activity of an operator. Most often it is monotony and fatigue that leads into decrease of attention and micro-sleep.

Micro-sleep is short-period decrease of attention, which is due to short-period first phase of synchronous sleep .

Our workstation specializes in measuring electrical brain activity. Electronic brain activity rises by synchronization of large population of neuron cortex near thalami-cortical oscillation. Brain activity, is scanned by electrodes, that are placed on a surface of a skull and potentials transcribe in time EEG curve.

EEG is measured according to international scheme designed by H. Jasper, so-called 10/20 system, see figure 1. Individual brain areas are termed font: Fp - prefrontal, F -frontal, C - central, P -parietal, O - occipital, T - temporal. Odd numbers denote left hemisphere and even numbers denote right hemisphere, character **z** (zero) means center between two hemispheres. Mode scan of EEG is different, we use joint referential electrodes most often connected to both earlobes (A1, A2).

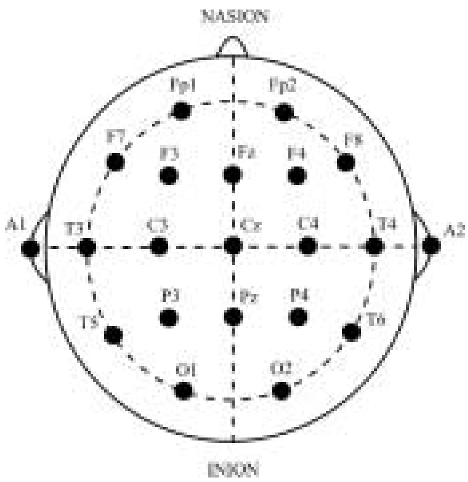


Figure 1.
Allocation of electrodes according to international system “10/20”

The EEG recording measured on the skull of human operator has a very little energy and so electric potential is on order of only tens of µV. Therefore we are using electrodes incased in plastic and transmission from surface of the skull to the electrode is enhanced by conductible gel (decreases impedance) or we use electrodes tin or Ag/AgCl, which also use conductible gel as a means of transport.

Resulting EEG record is processed with help of Fast Fourier Transformation (FFT) and single spectrums are created from them. Fundamental brain frequency is: delta (0,5 - 3,5 Hz), theta (4 - 7 Hz), alpha (8 - 13 Hz) and beta (14 - 30 Hz).

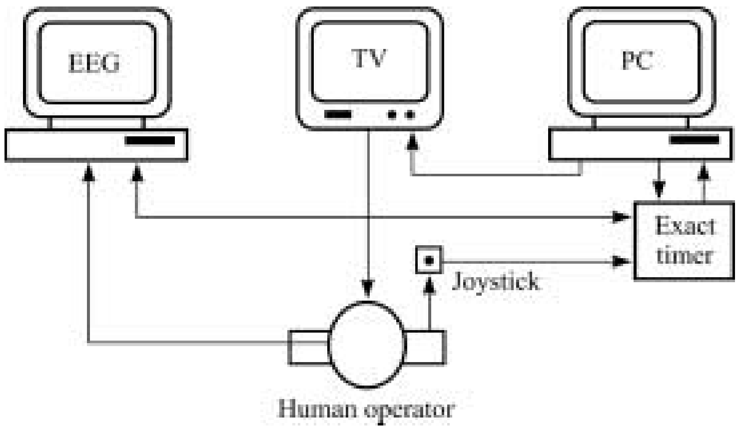
By comparing spectra of different states of human brain (vigilance, mental activity – reading, counting, drowsing, sleep) we can determine characteristic distribution and representation of single frequency for existing state.

3. Measuring decrease of attention in laboratory

As noted above, attention of human operators, Constantly changes over the time. In order to determine subjective limit of decrease of attention of the operator we measure the change in his reactionary time.

To ascertain the beginning of micro sleep we measure reactionary time – length of time from sound or optical stimulation - based on research of these times we ascertain intensity of micro-sleep till the first phase of synchronic sleep begins. This measurement is done by an external timing module that is connected to both computers and it records precise reactions of the human operator directly into EEG curve on the second computer, see figure 2.

Figure 2.
Diagram of EEG recording
with reaction times



To simulate conditions of human operator in traffic, we show the tested person a TV screen with a video showing similar view that he sees during his long hours of duty. At the same time we force the operator to react to several visual or sound cues.

After recording EEG with reaction times to an accuracy of milliseconds, we process this information with FFT and obtain a spectral curve. The human operator is faced with three situations: a) vigilance (180 – 400 ms); b) relaxation (400 – 800 ms); c) sleep and micro-sleep (800 – 1000, 1200 ms); see figure 3.

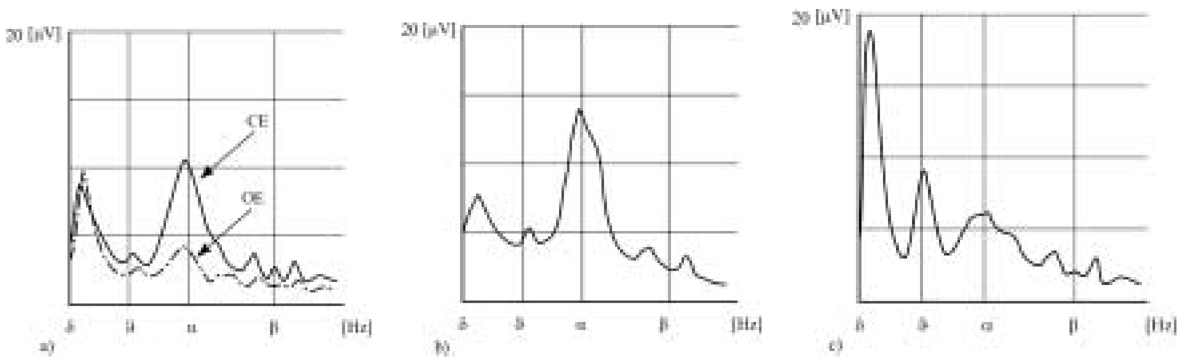


Figure 3.

Spectrum EEG of human operator found in three situations near meters reaction times (CE – close eyes, OE – open eyes)

Recording was carried out on the operator who was sleepy and shortly after his working hours. Recording of reactionary time was accompanied by sound cue assigned at the even and odd intervals when operator was falling asleep as shown by the EEG curve starting to disintegrate.

Since recording has been done in laboratory conditions, the reactionary times are disproportionately lower than they would be in practical application. Later on we have used sound cue only, because human brain responses faster to the sound cue then to the visual cue whose path to the consciousness is longer.

If the operator gets into micro-sleep, the sound cue will wake him up much faster than a visual cue, because excitation of the optic system take longer than the acoustic system. Therefore reaction to the visual cue can take quite a long time which might lead to a catastrophe.

4. Measuring on the car simulator

Measuring on the car simulator was similar to measurements in a laboratory. We recorded EEG and measured reactionary time, where the stimulus was sound, see figure 4. Measuring the decrease of attention was more realistic on the car simulator then in the laboratory. The driver observes the results of his driving the simulator. Connection of recording equipment of EEG and measuring equipment of reactionary time was similar to the laboratory’s conditions.

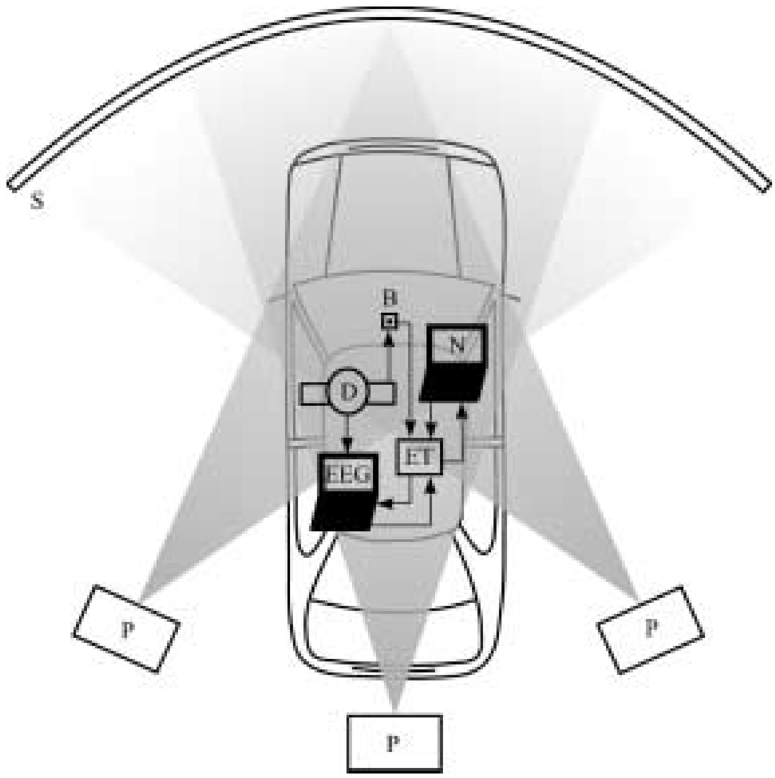
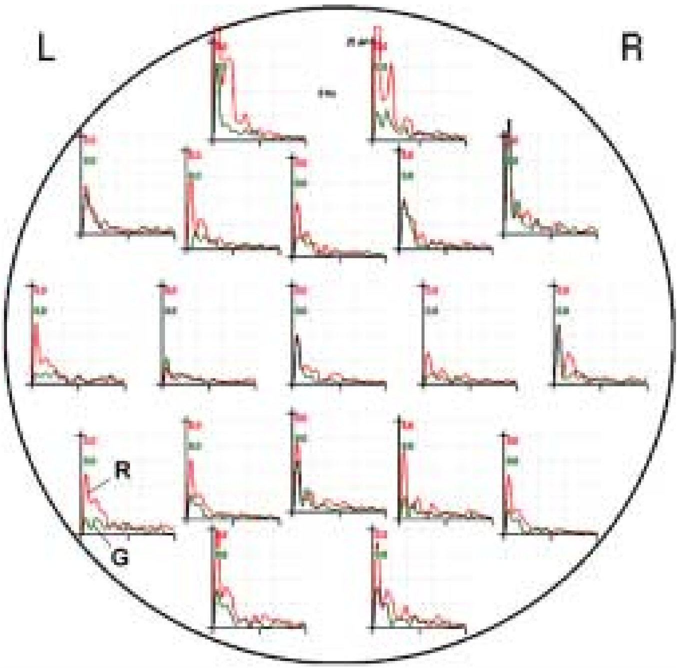


Figure 4.
Measuring of EEG on the car simulator
B - button
D - driver
EEG - recorder of EEG
ET - exact timer
N - notebook
P - projector
S - screen

We verified on the car simulator, that reactionary times of driver are longer than reactionary times we measured in the laboratory. Latency of the driver is prolonged about 200 ms. In traffic it is probable that latency of driver will be longer. We verified our previous measurements on the car simulator. The UCF simulator is an accurate representation of real situation. We could try situations which cannot be tried safely in traffic.

After recording the EEG we evaluated data by using FFT and the results are worked in a spectral curves; see figure 5 and in a spectral maps; see figure 6. Red spectrum curve (R) was metering in a state before sound stimulus, when driver was fatigued and started to decrease his attention. Green spectrum curve (G) was metering in a state after sound stimulus, when driver was “waked”. Length of latency was 1078 ms. At the spectral curve is possible to see a distinct change in the state of consciousness before sound stimulus and after sound stimulus. Sound stimulus is suitable for warning at dangerous decreases in attention.

The spectrum maps show quantity basis frequencies over individual area of brain. From the maps it is evident how frequencies change for each individual’s state. Before the sound stimulus, there are significant delta and theta frequencies (map 1). After the sound stimulus, there are significant delta and alpha frequencies (map 2), but the delta frequency is not significant as map 1.



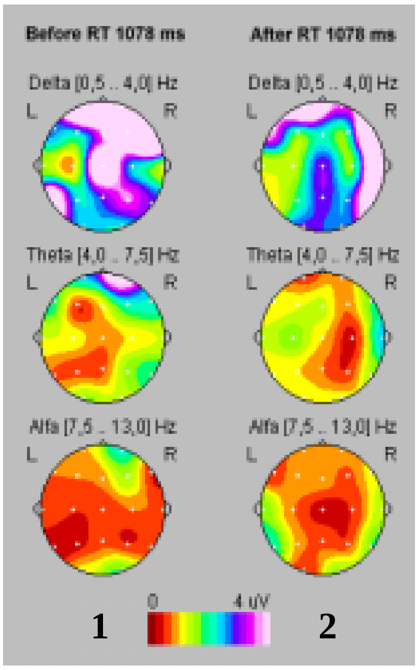


Figure 5.
Curve of spectral analyse
G - green spectrum – vigilance
R - red spectrum - fatigue - micro-sleep

Figure 6.
Map of spectral analyse
1. map of spectrum - fatigue - micro-sleep
2. map of spectrum – vigilance

We could verify that the decrease of attention of the driver on the car simulator, was similar to that realized in laboratory conditions. We can use this experience of measuring decrease of attention in laboratory and apply them in realistic traffic situations. Measuring on the car simulator is cheaper and more safety then measuring in the traffic.

5. Measuring decrease of attention in traffic

We need know for measuring in the traffic, what areas are suitable for detection of EEG on the skull. It is not realistic that engine drivers, truck drivers, or other drivers wear a measuring cap. The EEG cap has nineteen electrodes, but for a driver it is not comfortable and it does not need this many electrodes. For detecting the decrease in attention it is possible to use only one properly located electrode.

Therefore we recorded EEG of driver in laboratory and we specify areas for measure of EEG in the traffic. Then a human operator has only from one to four electrodes, which are locate in chosen areas on skull of driver. The areas are: P - parietal, O - occipital and T - temporal

On the figure 7. are areas of skull, where is possible to measure EEG with fewer electrodes. Areas are primarily at the rear of the head, because EEG signal has minimum artifacts (it means that useful EEG signal is not distorted). Of course application of electrodes are simpler.

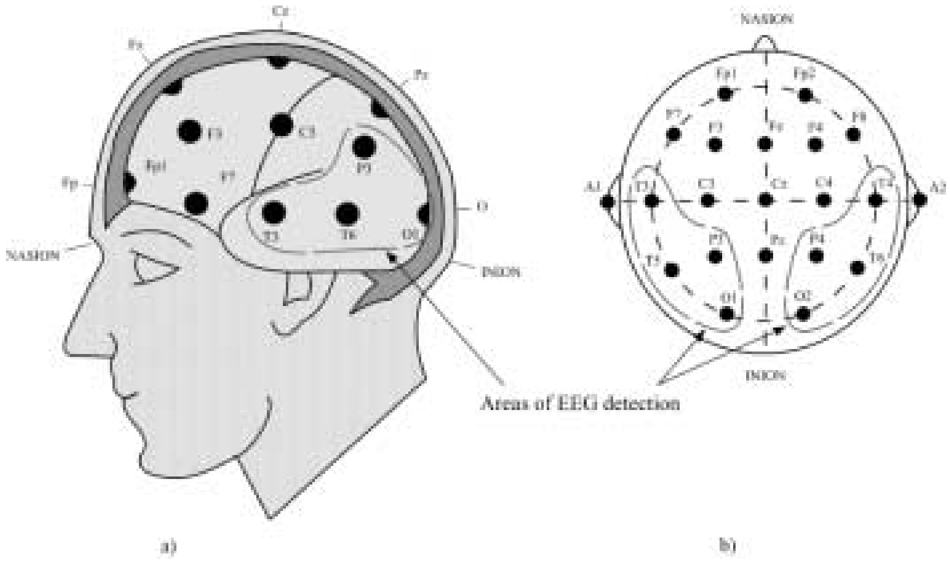


Figure 7.

a) Area of EEG detection - side-view

b) Area of EEG detection - top view

To record EEG in traffic we made a single-channel small unit, which records EEG and saves up to two hours of data. The measuring unit has two parts, where first part is source and second part is recorder of EEG signal. The small unit is shown on the figure 8.

Figure 8.

Measuring unit

A handicap of this measuring unit is that it can only record the EEG signal, but evaluation is made off-line. For traffic experiments it is sufficient. Recorded data are consistent with data recorded in the laboratory. Our next equipment will record the EEG and make evaluations in real time.

6. Conclusion

At first glance a decrease in attention of human operators might not necessarily be a big problem when we deal with computer-operated systems with multiple-control protection. But if a large failure occurs on a computer operated system, it is matter of seconds when human operator has to decide what is the most important thing to do.

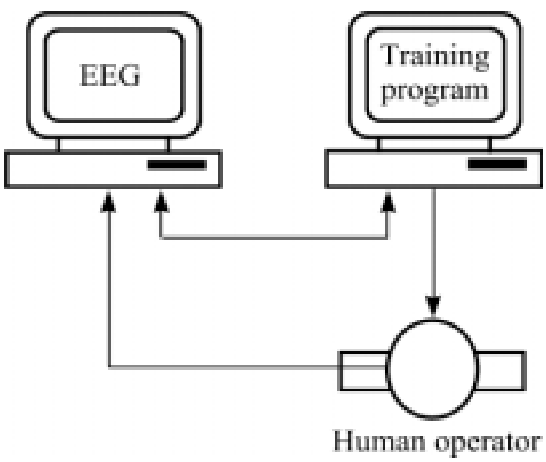
I think I do not have to mention mistakes that happen during critical situations in the field of transportation and energy. One of the possible causes is carelessness of the operator that comes out of monotony of work, from fatigue or even from neglecting regulations.

Possible prevention of dangerous situations is multiple-protection of appliances beginning with visual cue affecting the operator and ending with several sound cues of different intensity with the possibility of automatic system-turn-off. There are cases when appliances cannot be cut off from service for several different reasons, which might include material and financial damages. Therefore we need an attentive operator who will recognize such problems in time and will be able to solve them.

One of the possible methods that help to key up optimal affection of human brain and ensure the highest possible efficiency of the operator and at the same time to increase resistance against micro sleep is exploitation of biofeedback.

Our workstation contains a device that exploits biofeedback to affect treatment of several brain dysfunctions and enables to increase efficiency of human brain by his auto-stimulation without use of medications or physical intervention. Biofeedback with help of specially modified software transform electric signal to the brain on basis of simple training program, which is controlled by his brain activity, see figure 9.

Figure 9.
Diagram biofeedback



7. References:

[1] Bena E., Hoskovec J., Stikar J.: Psychology and Physiology of Driver (in Czech). Prague, Publisher Transporting and Communication, 1968.

[2] Faber J.: Electroencephalography (in Czech). Prague, UK, 1992.

[3] Faber J., Novak M., Prenosil V., Vydra L.: Diagnostic, Detection and Predicate micro-sleep. Development No. LSS 58/99 (in Czech). Prague, 1999

[4] Gevins A.S., Remond A.: Methods of analysis of brain electrical and magnetic signals. Handbook of electroencephalography and clinical neurophysiology. Amsterdam-New York-Oxford, Elsevier, 1987.

[5] Novak M. a collective: Artificial neuron network, theory and application (in Czech). Prague, C. H. Beck, 1998.

[6] Rechtshaffen A., Kales A.: A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects. Maryland, Bethesda, 1968.

[7] Svatos J.: Biological signals I - Genesis, processing and analysis (in Czech). Prague, CTU, 1995.

[8] Tichy T.: Selection of significant parameters of drivers` attention decrease. Dissertation. CTU, Prague, 2000.

[9] Tichy T., Leso M., Faber J., Novák M.: Problems of human operator vigilance decrease - detection and warning. Development No. LSS 73/00 (in Czech). Prague, 2000.

[10] Tuma J.: When with tunnel turn to fiery hell. Technical weekly 49/99 (in Czech): 16.

[11] http://teach.bhs.mq.edu.au/~tbates/imaging_techniques/EEG/EEG.html