The Basic Forms of Learning and Thinking

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Any medical treatment should be combined with psychotherapy. Frequently, we provide it rather unwittingly through our “good advice”. But it should be more systematic and targeted. During the session, electroencephalographic biofeedback (EEG BF), or the use of feedback and EEG for anxiety, attention deficit disorder, hyperactivity or epilepsy treatment, should be also accompanied by verbal contact of therapist and patient.

This article will deal with the following categories: learning, memory, and thinking and speech. First topic will deal with learning and memory because they are two sides of the same coin. These two complex concepts are of fundamental importance. Despite all the efforts, these concepts are not fully explored. Therefore, some views of this issue are will be introduced.

Learning and memory

Psychophysiology of memory can operate with **the concepts internal and external mechanisms, physiological and pathological forms**. Thus there are four possible categories of learning and memory: internal physiological, external physiological, internal pathological and external pathological.

Internal physiological mechanisms of memory subsist in thalamocortical reverberating system (**TCRS**), septo-hippocampal system (**SHS**), which is basically the main part of limbic system (**LS**), and in the activity of **ponto cerebellar nuclei and pathways during REM sleep** (see fig. 1). For these assertions a number of experimental and clinical evidence is known, e.g. pre- and postnatal insufficiency of REM is often associated with oligophrenia, dementia, or epilepsy. These mechanisms are genetically defined; not only people but also all mammals have these mechanisms well developed since birth. Briefly, we are talking about the developmental influence of **nature**.

External physiological mechanisms subsist in the dyadic relation with mother from birth, i.e. in the “secure attachment” and also in upbringing and education that follows – briefly talking, in “cultural genesis”. It is thus the external influence of family, community and school – the **nurture**.

Internal pathological mechanisms of learning and memory are inherent, e.g. Down’s syndrome, or presenile and senile degenerative processes, e.g. Pick’s disease or Alzheimer’s dementia. These mechanisms also include congenital degenerative diseases such as Wilson’s disease with following symptoms: epilepsy, hyperkinesis, and dementia caused by copper accumulation based on lack of the protein carrier called ceruloplasmine.

Very interesting is Moffit’s research (2002) which establishes deficiency of X chromosome at some male delinquents. This organelle defines not only gender, but also a number of enzymes, e.g. monoamine oxidase inhibitors. Lack of these inhibitors can cause hyperdopaminergia that leads to increased aggressiveness. Women have two X chromosomes, men have only one. The X chromosome at males is paired with relatively small Y chromosome that defines male gender. Therefore, women have the possibility to compensate the first imperfect X chromosome by the second X chromosome from the other parent. One of the X chromosomes is most probably normal. Moffit found out that this genetic deficiency is not enough for criminal career. It is still necessary to fully experience unfortunate youth with many psychotraumas; only then this latent anetic and aggressive psychopathic nature may manifest. Life is very complicated and **fate probably depends on interaction of many factors, natural and social (nature and nurture)**.

Very similar can be other deviations, such as ADHD syndrome, where approx. 40 genes are suspected from causing the symptomatology of these disorders. The cofactors of non-genetic nature such as diseases of mother during her pregnancy including eclamptic complications (diabetes, epileptiform paroxysms, dyspeptic disorders with consequent deficiency of vitamins and proteins, drug addiction etc.), perinatal events (hypoxia, high forceps, turbid amniotic fluid, long latency between rupture of amniotic fluid and delivery, strong neonatal hepatitis), as well as any preschool events (high fever, somatic and psychological traumas, disharmonious family etc.) are also present.

At the well-treated epilepsy, psychological disorders almost do not appear. But if the epileptic focus (EF) is present in LS, medicinal semi-persistent syndrome that on one side resembles “neurosis” (paroxysmal anxiety, panic attacks, derealisation, insomnia) and on the other side resembles “psychosis” (delusional apperception, autistic behavior, optical pseudo delusions, synesthesia) may develop. Also, as seen in epileptosis (Faber 2003), simplex and complex partial seizures may happen.

External pathological learning and other external influences. Independent (i.e. isolated, without other influences) “pathological learning” is actually “encephaloprogramopathy” given by abnormal upbringing during the period of attachment, i.e. “insecure resistant attachment,” or “insecure avoidance attachment” (Bowlby 1995, Faber a Pilařová 2001). Environment with iodine deficiency causes cretinism; environment with the excess of fluoride causes decreased intelligence. It can also be postlesional psycho-syndrome, e.g. posttraumatic, postencephalitic, post intoxication (carbon monoxide, lead, mercury, chronic ethylism /Korsakoff syndrome or Wernicke’s encephalopathy/, addictive drugs etc.).

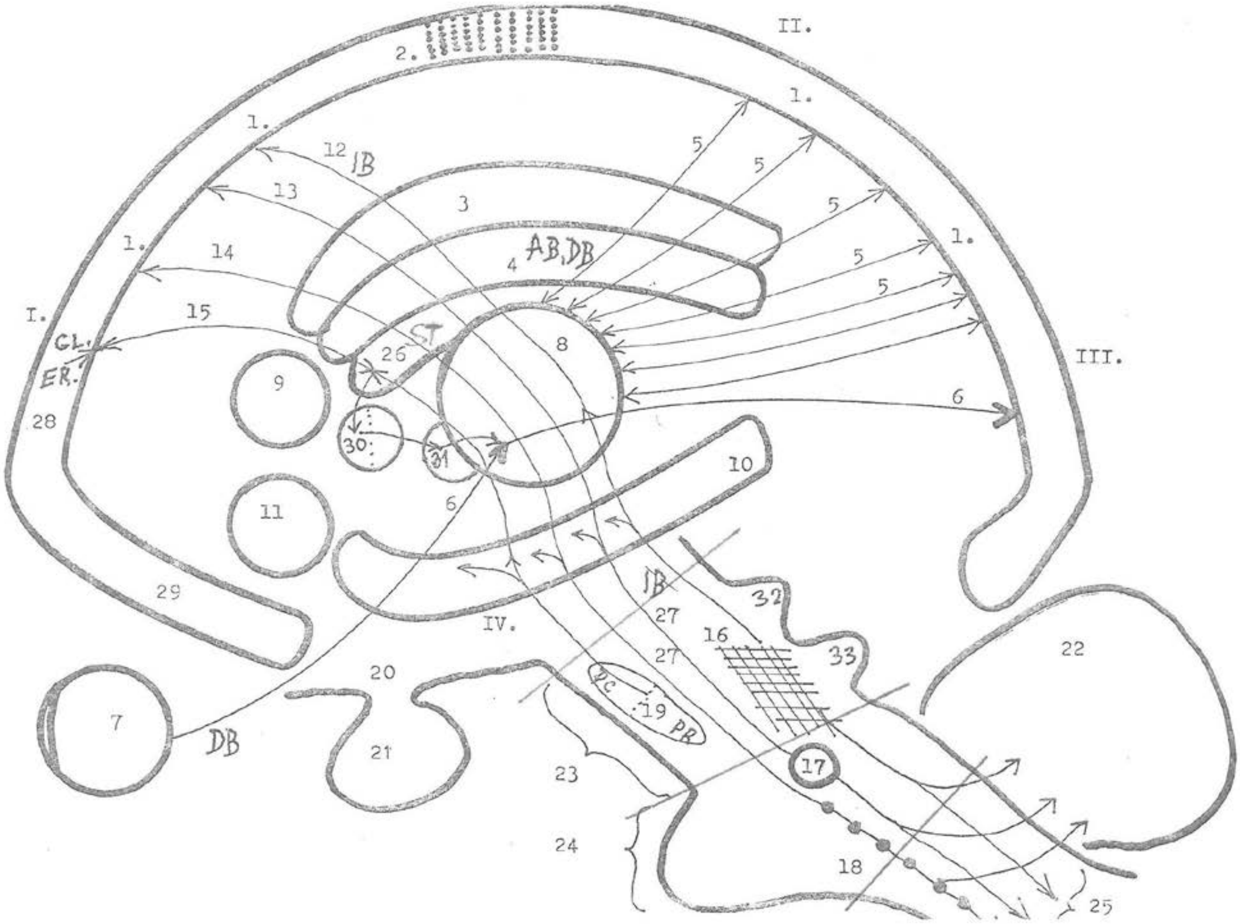

Fig. 1 Longitudinal sagittal cross-section of the brain.

The structures are described from right lower part up: medulla oblongata (25), which contains the centers of breath management, blood pressure and heart rate; NR = raphe nuclei (18), which are non-specific humoroergic centers with long fibers (14). These centers release transmitter at their synaptic terminals, in this case serotonin that regulates synchronous sleep (NONREM) and good mood. Downwards, oblongata extends from cranium (skull) through the foramen magnum and continues as the dorsal spinal cord (medulla spinalis).

Upwards, oblongata continues to pons Varolii (24) where the centers for paradoxical sleep (REM) regulation, e.g. noradrenergic locus caeruleus (LC) (17) and acetylcholine centers, nucleus pedunculopontinus and nucleus laterodorsalis, are located. From these centers (13) long fibers go to different levels of the brain, cortex (1) including.

Massive fibers lead from the pons to the cerebellum (22). These massive fibers come from vestibular apparatus, spinal cord and cortex and are important for balance, gross and fine movements and probably for mentation. During stimulation of cerebellum the epileptic activity and psychotic symptoms are suppressed. These diseases have atrophy of the cerebellum.

Upwards, the pons Varolii extends to mesencephalon (23), or the midbrain where the reticular formation (16) is located. Using long and furcated fibers (12) the reticular formation influences our vigilance. It is also called the ascending reticular activating system (ARAS). Coliculi rostrales (32) are the main subcortical optical centers. Coliculi distales (33) are very similar acoustic centers.

Mesencephalon passes into hypothalamus (in the picture on the left) (20) which is the highest neurovegetative-hormonal center. From mesencephalon the fibers go to hypophysis (21) where the control hormones for endocrine glands, such as AHR (adrenocorticotropic hormone releasing), are released into the bloodstream. The hormones go through blood vessels from hypothalamus to the anterior hypophysis where they cause the ACTH (adrenocorticotropic hormone) secretion. ACTH is then released into the blood where it causes adrenaline and corticosteroid secretion (approx. after 10 minutes). Adrenaline is released from the adrenal medulla and corticosteroids are released from adrenal cortex. This is the main stress pathway by which the body responds to various kinds of stresses, either somatic (pain, hunger, cold, heat, fever, lack of sleep) or psychic (agitation, anger, externally caused sadness etc.). Hanel (1999, according to Holmes and Rahe, 1967) shows the stress range in percentage: death of life partner (100%), divorce (73), illness or injury (53), marriage (50), pregnancy (40), social problems (39), a new family member (39), financial problems (38), change in living conditions (25), problems at work (23), changes in working time (20), moving (20), sleep disorders (16), holiday (13), Christmas (12).

On the base of the temporal lobe archicortex, i.e. hippocampus (10) with three layers of neurons is located. In hippocampus memory register, emotional center, and motivational impulses are placed. At the end of hippocampus lies amygdala (11) which is also a center of emotions, sometimes called the "fear center". Upwards lies thalamus (8, rhythm donor for neocortex) where all sensory pathways converge and from where myriads of fibers (5, 6) go to neocortex (1, has six layers of neurons and occupies 90% of all cortex). Neocortex is the center of concrete and abstract thinking, perception, vigilance, consciousness, speech etc. Striatum (26, ST) and pallidum (30) belong to the basal ganglia with motor and memory functions. Corpus callosum (4) consists of about 500 million fibers that connect left and right hemisphere. Women have more of these fibers. Cingulate gyrus (3) belongs to the neocortex but functionally it is closer to the limbic system. The eye (7) sends millions of fibers to the thalamus. Septal nuclei (9) are the rhythm donors for hippocampus.

The letters represent the cybernetic analogy with a "chip": IB = instruction buses, a set of program-bearing fibers, i.e. the instructions how to process the data; DB = data buses, i.e. the fibers conveying specific information from the senses (DB); AB = address buses, i.e. the fibers conveying the data to the next addresses where they are further processed.

A dynamic view of teaching monitors this process in temporal aspect. It is an **immediate (IM), short-term (SM) and long-term memory (LM)**.

During the vigilance, information through our senses (eyes, ears, touch, smell, taste) are being received and then converted into neuronal signals – impulses. These impulses travel by hundred billions through the whole brain. They are to some extent synchronized, i.e. gathered into groups; that is also the reason why they can be easily observed as waves using electroencephalograph (EEG).

Activation of peripheral sense, e.g. eye, ear, where the light (wave motion of electromagnetic field) and sound (acoustic wave motion of physical environment) is transformed into the sequence of neuronal impulses (of electrochemical essence) in nerve cells. NENÍ CELÁ VĚTA. It is action in an interface that takes place in two different environments, i.e. in the outer world and inner world of the living organism. It is about the speed and accuracy of portrayal of the outer world into the internal structures. It is, however, rather inaccurate, or "fuzzyficated". External stimulus creates a sequence of impulses called SNI (sequence of neuronal impulses) where the "images" of the outer world are encoded. From the psychological point of view it is called perception.

The impulses go from the senses to the thalamus. The impulses are circulating between the thalamus and cortex rather a longer time; that is why we talk about reverberating thalamocortical system (RTCS). Taking it logically, this circulation is an **interaction that causes more accurate perception, "deffuzyfication", and identification of the perceived – cognition.** Circulation of the impulses in RTCS is not only the foundation of immediate memory (IM), but also the mechanism of consciousness: awareness of oneself and one's environment, awareness of being aware of one's existence and one's psychic processes. Professor Vondráček (1959, 1995) was calling the last term "ultrasensibility." It can be a foundation of second-signal system (Pavlov, 1925). It is the first step towards creation of psychological self (Ego) and noogenesis.

RTCS produces not only regular, but also random variables, i.e. on the one side, it is very difficult to control such a system with hundred billion neutrons, but on the other side, this system provides many degrees of freedom with the possibility to suppress the functional fixation, to violate the established dynamic stereotype, or to realize a logical leap. This kind of system can produce psychosis or epilepsy, but it can also produce genius. In his anamneses of psychotics, Vondráček (1959) describes more frequent occurrence of exceptionally intelligent people. Seneca quotes Plato: "In vain does one knock at the gates of poetry with a sane mind," or Aristotle: "No great mind has ever existed without a touch of madness."

During IM a temporary memory traces, most probably in the form of local depolarization of neuronal membrane that leads to the opening of calcium channels and to the intracellular influx of calcium, must be created. Here the phase of impulse circulation ends and **a temporary fixation of memory trace occurs – in other words, the immediate memory (IM) crossed to the short-term memory (SM)**. The described processes are completely unconscious.

The hypothetical enzymes activated by calcium are the main stimulant of so called transcriptors, e.g. CREB. It can find a suitable "locus" in the nuclear DNA of neuron, copy a part of DNA and splice the copy in the form of messenger RNA (mRNA). This is the process of **transcription**. Using the mRNA, a special protein in the cellular polysomes is formed (e.g. synapses strengthening protein, SSP). This process is called **translation**. SSP strengthens those neuronal membrane places that are strongly depolarized due to the received intensive impulses. A certain spot on the neuron whose irritation is suitable to "remember" is thus fixated (Hall 2003, Fields 2005). Other substances may be involved in the process, e.g. protein S-100, or according to Hydén (1974) "memory" proteins that compared to normal proteins have predominance of certain amino acids, e.g. glutamine. Ampakines should be memory enhances. These processes change the short-term memory (**SM**) into long-term memory (**LM**). This mechanism of memory traces fixation in neurons is probably very complex and requires a longer time period for its realization. Therefore the mammalian brain uses a period of relative calmness, i.e. sleep. Battaglia et al. (2005) shows a certain arrangement of impulses (SNI) during rat's movement in the maze and its relatively accurate repeating during sleep stages.

Experimental animals and people have increased NONREM amount after a physical load; after a psychical and emotional tests the REM sleep is increased. Different sleep stages are very important for endocrine system. Due to capillary fenestration in plexus chorioides, eminentia mediana hypothalami, area postrema in oblongata, and in epiphysis, the high molecular weight substances such as proteins or hormones can get directly from bloodstream to cerebrospinal fluid, brain tissue, and can also travel the opposite direction. This is very important for clinical information: sleepy child that experiences domestic quarrels does not have well-regulated brain not by sleep nor hormones. Prosser et al. (1997) finds increased plasma levels of GABA at 115 children with psychiatric and behavioral disorder and with ADHD. Presumably, at these syndromes it is not neuronal but humoral dysregulation. We found frequent perinatal asphyxias, genetic load, higher levels of lead and lithium, immune disorders, and lower levels of hemoglobin at 30 ADHD children (Faber 2003, Faber et al. 2001, 2002).

Centers in the brainstem regulate vigilance, sleep, and affect the secretion of hypothalamus and hypophysis hormones. These hormones (e.g. prolactin, somatotropic hormone, testosterone etc. secreted mainly during sleep) have a protective effect on brain; at the same time they improve learning and by improved protein synthesis they also enhance long-term memory (LM). Frequent use of certain operations further improves memory; also the neurons form new synapses and so-called spines (i.e. a small membranous protrusion from a neuron's dendrite where several synapses are connected). Thus, **memory traces in neural tissue become "petrified" and software becomes anatomical structure – a hardware**.

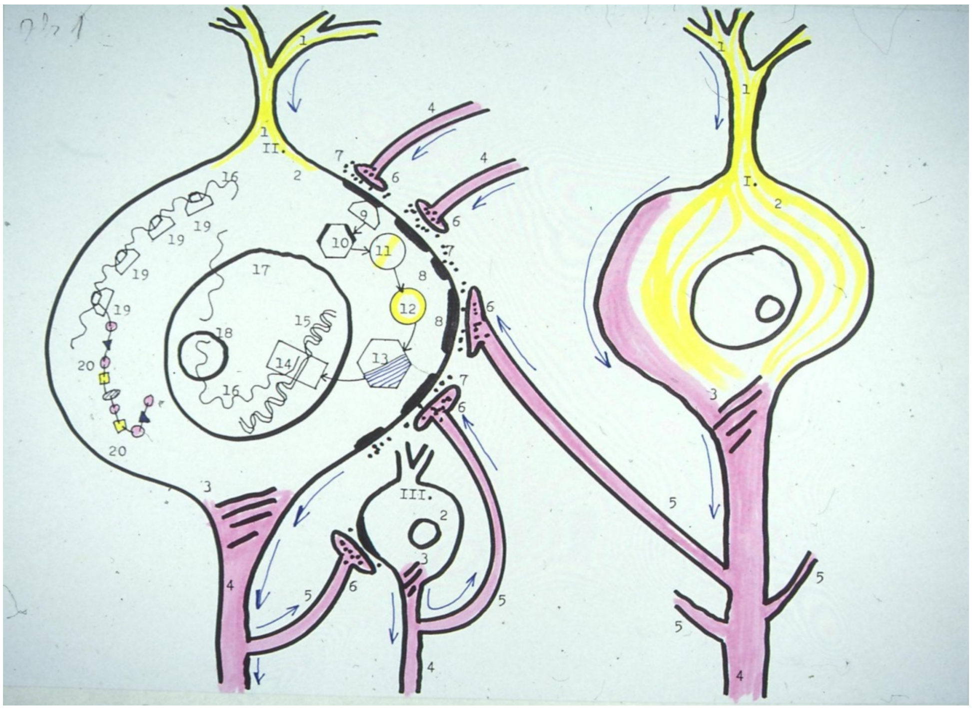

Fig. 2 (I., II., III. = neurons; 1 = dentrites; 2 = neuron soma; 3 = axon hillock generates an impulse that travels along neurite 4 to other neuron III.; 5 = collateral branching of neurites; 6 = synapse)

Some places in neuron receive in synapses larger number of impulses than other. These places are then depolarized and can cause various metabolic reactions: reaction A (Kandel and Schwartz 1985), reaction B (Hall 2003, Fields 2005).

Reaction A: drops of neurotransmitter (e.g. acetylcholine, dopamine (7) activate G-protein (9) in postsynaptic density (8); G- protein then activates cyclic adenosine monophosphatase (cAMP, 10) which changes ATP (11) to cyclic adenosine monophosphate (12) that activates protein kinase (13). Regulatory subunit of protein kinase enters the nucleus of the neuron and causes transcription (14). mRNA (16) produced by this process travels from the nucleus and binds with a series of ribosomes (19, polysomes). The translation that follows leads to protein synthesis. Protein (20) obtained from the protein synthesis usually serves as a catalyst, which is then a co-producer of another transmitter or becomes a microstructure of neuron.

Reaction B is as follows: in the synapse neurotransmitter (e.g. glutamate (7)) transmits a stimulating signal in the form of impulse which than travels from one neuron to another. It causes postsynaptic (8) local depolarization, opening of the calcium ion channels, and production of hypothetic signal molecule (HSM, 21) which activates “synapse-nucleus axis.” Nucleolus (18) also contains RNA. Repeated stimulation and HSM activate CREB protein (17) in the nucleus of the neuron. CREB is a transcription factor, which means that it causes transcription. During transcription, genetic information from DNA (15) is copied to messenger RNA (mRNA). This process is very similar to reaction A. Copy of DNA, i.e. mRNA travels from the nucleus and binds (spojit se) with polysomes (19) and then due to translation protein synthesis occurs. A new synapse-strengthening protein (SSP, 20, 21) is created. SSP strengthens specifically activated postsynaptic receptors (e.g. glutamate) and thus in the long term increases their susceptibility. In these places are so called increasing memory ampakines effective. That is the way long-term memory is realized in neuron. Different mechanisms of memory traces can be imagined, e.g. post-stimulating activation of fos-like substance (Merchant-Nancy et al. 1992) or ultrafast folding protein. Therefore, cognition improvement occurs after medication such as phenserine, donepezil, rivastigmine (used in treating Alzheimer’s disease), modafinil (used in treating nacolepsy), or methylphenidate (used in treating ADHD syndrome).

At last, traditional static view of the psychology of memory and learning will be mentioned. Declarative (explicit) and non-declarative (implicit) memory are being distinguished. **Declarative memory** is further divided into **episodic memory** (we remember what happened and how it happened, e.g. events on Christmas Day, school trip, theatrical performance etc.), and **semantic memory** (we also keep in mind bare facts without remembering where and how we learned them, e.g. data from history classes, geographical, language, or musical knowledge, mathematical or chemical formulas). Anatomic center of these memory engrams is in particular in hippocampus, which is very interesting because the center of emotions and motivation impulses is identical. However, memory is also influenced by a part of hypothalamus, e.g. corpora mammilaria, fornix, septal nuclei and a part of ARAS. It is a general experience that during learning, interesting topics are easier to remember than wearisome topics. However, weariness or dullness of a topic is very subjective experience.

Non-declarative memory is further divided into **skill** (cycling, swimming, craft skills), word **completion** (which is usually tested by sequence of words that shall be remembered and then retested by completing parts of words to whole words). This type memory is further divided into **non-associative** learning (sensitization; originally irrelevant stimulus becomes after repeated exposure tedious, unpleasant), desensitization (originally important stimulus, e.g. sound of the horn, becomes after repeated exposure unimportant if it is not accompanied by a relevant event), habituation – which resembles desensitization (with the only difference that the original stimulus was never important), and finally dishabituation – which resembles sensitization (with the only difference that original habituated stimulus becomes important because it begins to accompany an important event, e.g. rat starts to be alarmed again at the soud of horn because this already habituated stimulus begins to be accompanied de novo by electric shock to the deck of the cage).

Another **type of non-declarative memory is associative learning**: classical (Pavlov) and operant conditioning. Anatomical structures of the non-declarative memory should be located in cerebellum and in basal ganglia (Atkinson et al. 1995, Bouchal a Konečný 1966, Říčan 1972).

According to Pavlov, non-declarative associative learning is according to classical conceptions based on two external stimuli and their constant temporal distance and dependence: the first one is "warning" conditioned stimulus (e.g. light, touch, and sound; CS), the second is "imperative" unconditioned stimulus (e.g. serving of a food, painful stimulus; US). After the conditioned reflex is developed, by repeating of both stimuli CS even without US can induce a reflexive response (e.g salivation after light application). It is an answer obtained by learning, i.e. by temporary dynamic connection. If this connection is biologically pointless in the future, i.e. if there is no serving of food after the light is switched on, this reflex will become extinct. In other words, without occasional strengthening, i.e. linking of both stimuli (CS and US), conditioned response can extinguish.

Non-declarative associative operant conditioning (Sterman and Friar 1972) is based on one internal and one external stimulus; in addition, this type of conditioning is inverse, or rather reverse (Dostálek 1976), i.e. the internal unconditioned stimulus (e.g. SMR spindle in EEG) appears as first and the following conditioned stimulus (e.g. reward) as second. At the beginning of learning, EEG BF is based on random presence of the desired EEG graphoelemente (GE), e.g. sensory motor rhythm (SMR).

TCRS still produce all rhythms from 1 to 30 Hz; it is only a matter of time when the SMR comes (with the frequency of 14 to 18 Hz). If the desirable GE (graphoelementes) appear, there is a reward, which the brain, especially the limbic system, "likes" and "wants" to repeat this situation again. This is the most extraordinary phenomenon in EEG history: **a will is transmuted into EEG change**. During a series of treatment sessions, this situation (fixation of EEG GE with a reward) increasingly repeats. The desired EEG GE are becoming more frequent; therefore, their features are more enforced, in this case (EEG GE= SMR) the motor inhibition (the child is in better control of him/herself) and improved attention focusing (the child concentrates better) (Howard et al. 1982, Faber et al. 2002). EEG BF, EMG bio-feedback, strengthening of anal or urinal (voiding) sphincters etc. also belongs to operant conditioning.

Any device that can sensitively measure electrical, metabolic, or oxidative changes can be used for BF. Even the NIRS (Near Infrared Spectrograph) that monitors the levels of oxy- and deoxyhemolobin in the cortex, was used for feedback several times. It was proved, that although the measured latency of the changes in brain is higher than in EEG, this device is also suitable for BF treatment.

R. Christopher deCharms et al. (2005) used very fast new fMRI device that worked in real time (real time functional Magnetic Resonance Imaging – rtfMRI). Higher speed allowed the proband to react quickly enough to every new situation. The authors found out that during this training the ability to control hyperactivity in the rostral (anterior) portion of gyrus cinguli (GC) is improved, and thus the ability to suppress pain and improve attention is also improved.

The evidence from isotopic studies (PET) showed that GC is also the place where physical and mental pain is felt (Posner and Raichle 1994). An increased activity in GC was found in depressed patients. Volunteers either experienced pain that was caused by burning (using hot objects), or they were "tested" using standardized psychological tests; at the same time, increased activity in the GC was found. This means that the mental anguish and physical pain has a lot in common and if it lasts for a longer period, it becomes unbearable and very stressful. These clinical observations were performed also in patients suffering from chronic pain. Pain is a significant internal noise; therefore, a suppression of pain leads to improved attention almost automatically.

J. Lévesque et al. (2005) used BF in 20 children with ADHD syndrome. The clinical experiment was accompanied by fMRI and Stroop psychological test. The results were promising: after the use of BF, the speed of correct answers was increased. It turned out that BF has the ability to improve the functions of certain brain structures, e.g. it increases metabolism of the upper left parietal lobe (Brodmann area 5 and partially area 7) and the frontal part of the aforesaid GC. BF was thus effective in places where selective attention is formed.

Thinking and speech

In every person there is an unconscious and automatic process of thinking (mentation, noesis). This process is given genetically and by elementary pre-school education. Its product is a thought (idea, noema). Even analphabetic individual associated thinking with a verbal process, i.e. the ability to understand and create words. Thinking can be divided according to various criteria; e.g. according to the ideas/imaginations by which thinking is accompanied, it can be divided into **motor, imaginative, and propositional thinking**. Motor thinking is a product of specific ideas about our surroundings, movement and behavior, reactivity. Its product is a movement or at least an idea of movement. The neurophysiological basis of thinking is TCRS.

Imaginative thinking is probably accompanied by sensory, especially visual ideas that are very clear in artists (painters); in musicians and composers are these ideas probably acoustic. Both types of thinking (motor and imaginative) are strongly carried out e.g. during paradoxical sleep. This shows that during this kind of sleep that includes dreaming also symbolic-atavistic and reactive way of thinking takes place.

Primitive concrete thinking during vigilance and dreaming takes also place at its lower lever in animals. It is associated with learning, memory, conditioned reflexes, and dynamic stereotypes. Experiments prove that successful learning in animals is followed by an increase in paradoxical or REM sleep. On the contrary, it is known that prior REM sleep disorder leads to a learning disruption. Something similar naturally occurs in people, with the only difference that learning load should be not only rational, but also emotional, focused more on prestige and “ego”. REM augmentation in people is also dependent on the personality type; according to Eysenck neuroticism scale (Cohen 1957), the REM augmentation is more significant and more constant in suppressors than in sensitives.

Propositional thinking is already more abstract process that takes place in more general ideas, in fact in terms; it is verbally and conceptually abstract. Therefore, it is developmentally, phylogenetically and ontogenetically more progressive. Presumably, propositional thinking is typical only for human mentation. It is also more effective and faster than factual thinking which is dependent on conditioned reflexes and specific events as it is in children under three years, in people with oligophrenia and in experimental animals.

Motor and imaginative thinking is less conscious, more automatic and it probably dominant during EEG BF training. On the contrary, propositional thinking is a more realized process, i.e. voluntarily constructed and less automatic. The aforesaid types of thinking are responsible for the formation of general ideas, or “terms” at specific levels that further developmentally escalate and are further hierarchically organized from primitive children terms (e.g. “apple, classmate, brook”) to more abstract term (e.g. terms like “homeland, duty, game, or love” in high school students), or later, to terms such as “principle, average, war,” or to high abstractions such as “truth, relationship, coefficient, modus, functor etc.” that sometimes originate from technical terminology.

Thinking thus forms terms that in a way represent more or less limited set of certain abstracted attributes of subjects (person, the mayor, Mr. Horak), objects (house, river, city), states (temperature, density), and events (storm, meeting). Terms have their names: from concrete to abstract, form specific to general, e.g. dog, beast, mammal, vertebrate, metazoon.

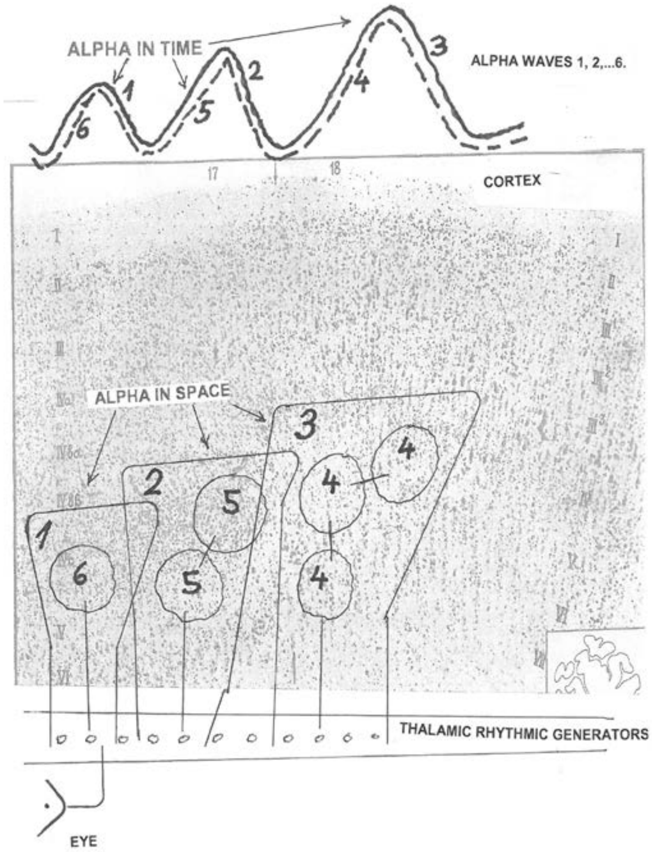

Fig. 3 At the very top, there is a diagram of three alpha waves whose amplitude increases (alpha 1 to alpha 3; alpha ascendens = ALAS); the second half of alpha spindle – the dashed line (alpha waves 4 to 6, alpha descendens = ALDE) illustrates the amplitude decrease. This is the behavior of standard alpha wave spindle: it is fusiform (spindle like) and it is produced by a reverberation of hundred billons impulses circulating between thalamus and cortex in a single second. It is also called "recruiting". The curve is a manifestation of TCRS activity which is drawn in time. The lower half of the picture illustrates how the process takes place in cortex area. The numbers written in strange trapeziums are the same alpha waves as the waves at the very top of the picture with the only difference that they illustrate the neuronal population borderlines. This population slowly increases (alpha waves 1 to 3) and slowly decreases (alpha waves 4 to 6). During ALAS, the neuronal population is growing enormously and a number of neurons, even those that are unsuitable, is activated. During ALDE, the number of neurons decreases because a form of selection takes place; during this selection the functionally unsuitable neurons are eliminated. A mathematical model of artificial neuronal network according to A. G. Ivachněnk and Müller (1984), Šnork (2004), and partially Berk and Tondl (1967) was used for this interpretation. (The little dots in the background represent neurons; it is an optic coniocortex of areas 17 and 18 with 6 layers according to Sarkisov and Filimonov 1955.)

Mentation and the development of speech probably went hand-in-hand. Some of Brodmann Areas (1906) are activated likewise during mentation and speech. The development of production of phonemes with **arthritic function** according to Heveroch (1913) could be localized to Broca's center in the areas 44 and 45. The phonemes are combined to form **morphemes**, i.e. the whole words such as mother, die Mutter, la mére, matka, mať, mater both in Latin and Greek. According to Heveroch, the word is already a **meristic function**. (It was Professor Pelikán, who revived Heveroch's ideas.) This function is localized to areas 45 and 46. At last, there is a function in brain for **sememe** which is a transcultural term, a general symbol for verbal terms. Sememe cannot be verbally expressed, but all people, even though speaking different language, know what the terms "mother, father, hunting, apple" or even more general terms such as "peacefulness, war, greed, comparison" mean. According to Heveroch it is called **mnestic function**. It is therefore a sememe to morpheme conversion that takes place in frontal lobe areas 46 and 47, i.e. conversion of the transcultural nonverbal symbol to verbal symbol that is then enunciated as a word or written as a graphic symbol (**grapheme**).

Analysis of the heard phoneme takes place in areas 41 and 42, analysis of the heard morpheme in areas 21 and 22. At last, a reverse process, i.e. a conversion of the heard morpheme or seen grapheme to sememe, takes place on the border between parietal and temporal lobe in areas 39 and 40.

Words naturally strongly facilitate the thinking and the interpersonal communication. However, thinking in non-verbal symbols is also possible, even though these symbols are probably less abstract, e.g. sign language of surdomutism people. Nevertheless, a highly sophisticated thinking with its own nonverbal specific graphic symbols also exists, e.g. in mathematics or music.

Mental and verbal form of a term is created in childhood and later on during whole life. If well-associated, both forms merge into one another and support and strengthen each other. PET findings to some extent confirm the Heveroch hypothesis, e.g. the central executive unit that lies in prefrontal area unifies the very abstract visual (area 8) and auditory (area 10 to 12) verbal components of a term. Phrenology loop is probably realized by subcortical, associative, commissural (especially prefrontal) fibers and in TCRS by pathways between the nucleus ventralis anterior thalami and premotor cortex.

The next association between the parietal (5 and 7) and temporal areas (21 and 22) is visuospatial (so called visuospatial scheme). It must be emphasized that areas 39 and 40 that lie on the temporo-parieto-occipital border resemble Hrbka's (1968) logaesthetic proprioceptive analyzer where the seen and heard words are converted into transcultural sememe. The latter center is probably the counterpoint of semantic area 47 that lies in supraorbital cortex and where the exact opposite is created, i.e. the sememe is converted to a spoken word.

Fractals and attractors in the EEG curve

No one doubts the complexity of the EEG curve. It is known that the curve "hides" many undiscovered information. We are often pleasantly surprised by the interesting results that the application of new EEG signal analysis brings. At the same time, the EEG curve is quite unstable, or quasistationary, and irregular, or quasiperiodic which is due to the excess of not only harmonic, but also inharmonic, or random variables (Faber et al. 1975).

A newer branch of mathematics that deals with chaodynamic events discovers that seemingly determinate complex events contain periods of noise. Evolution and sudden events in the universe, meteorology, and in our brain are good examples of complex systems that contain both regular and irregular cycles, occasional occurrence of "eruptions, storms, ideas, or seizures". The system behavior can be expressed graphically by trajectories. There are four primitive examples of the attractor or fractal behavior on the picture below.

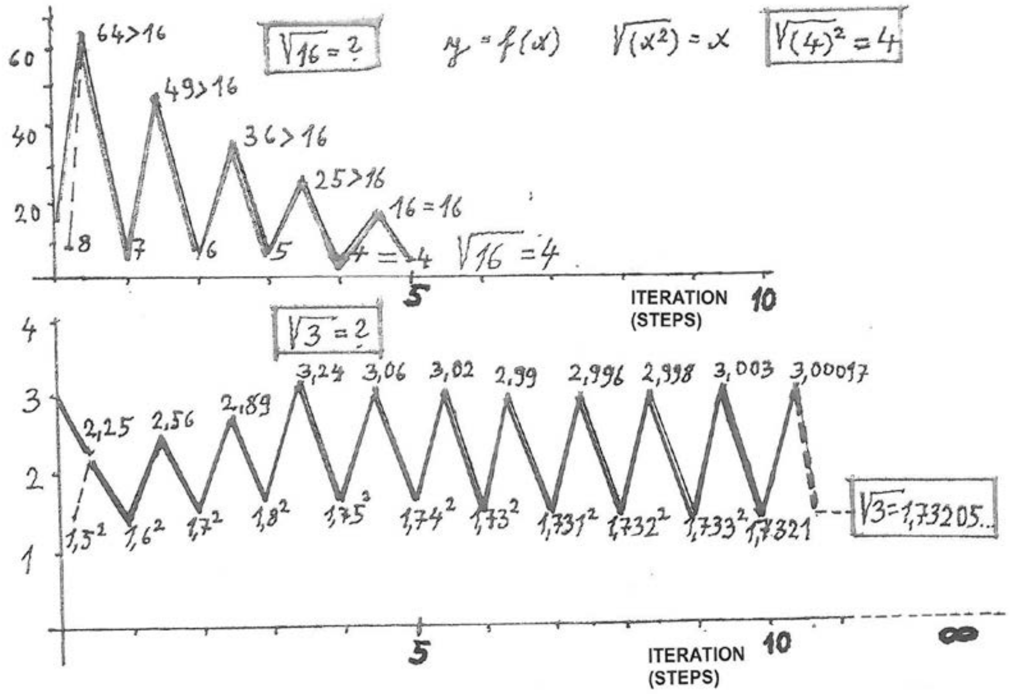

Fig. 4. The upper curve represents the "trajectory" of square root extraction of number 16. Each equation can be imagined as a system; ***x*** *variables are the inputs,* ***y*** *is the output, the equation itself represents the operation or transformation as in any other system. Square root extraction is similar to a computer square root extraction. We should find a square root of number 16. By estimation we take a number, (about a half from our number, which is 8) which we square and we find out, that the resulting number is too high (here, 64). Therefore, from 8 we take away one (7) and square it again (49), then we take away one again (6) and square it (36) etc. until we find the right number (4) which squared gives our number (16). That way we reached the goal, the definitive quiescent state similar to a state when the pendulum stops. It is a point attractor. After all, even here the processes of contractions take place and it is also an iterated function system.*

When doing the square root extraction of number 3, the proceeding is very similar. However, the trajectory does not end here. It approaches infinity because the square root extraction of number 3 (and analogously the square root extraction of number 2 or the Ludolph's number itself, 3.1415) is irrational, non-periodical; it approaches a certain number only "asymptotically" (1.73205…). Here the self-similarity is very apparent. In this case, the process never ends. The calculation can be an example of "fractal".

The French mathematician and astronomer Poincaré found that two close celestial bodies with a different in mass orbit the same center of gravity in exactly determined paths. The trajectory of this system could be called attractor trajectory with a cyclic course. However, the mutual gravitational relationships of three associated bodies are so complex that they can not be precisely defined; we can talk about fractal trajectory. Similarly in meteorology, the days with normal temperature, humidity, and pressure fluctuation can be described as of fractal behavior, but stable days with balanced parameters can be described as attractors. These natural phenomena are less regular than the differential equations calculations.

Let’s be more specific. The shape of clouds, the capillary localization in the body, or the perimeter of the sea coast can be considered fractals. Properties of the fractals are repeated in similar shapes regardless of the scale; the properties are usually complex, but mostly, they are always different and always similar. This is the self-similarity. The self-similarity in natural fractals (clouds, EEG curves) is less pronounced and less complex. They can be expressed using simple logarithmic equations. The classical differential equations would be very difficult to calculate and actually, they would be less accurate.

In the examples listed above we talk about Kolmogorov and Mandelbrot (KM) dimension which is always greater in fractals than the Euclid topological dimension; therefore, it is non-integral (e.g. grater than 1 but less than 2). The topological dimension of points with the same distance from the center is the circle. Nevertheless, the circle emerging from Koch dice with the recurring triangles that get smaller and smaller has always greater perimeter. Its KM dimension is non-integral again; it does not equal to 1 as in every other line (bisector, abscissa) and curve, but it equals 1.26. It is therefore obvious that this KM dimension could be used for an EEG curve definition.

We are trying to express the EEG curve by the simplification rate, or in other words by synchronization grade. The amplitude analysis (AA) is applied to the EEG curve: the maxims of positive and negative extremes are added up and then they are compared to medians. Here, the length of the process is half a second. The results can be considered as the formulation of stability and work activity of the EEG curve, thus a fractal in a way. For the state of mentation with open eyes, the number is 0.35 (in a specific epileptic A.F.A.); for the state of mentation with the eyes closed is the number 0.9 without a test; during NONREM 2, the number is 3 and finally, during absence of petit mal, the number is 16. The last two numbers represent a regime that is similar to attractor, with a certain physiological (NONREM) and pathological (absence) stability.

See the following figure 5.

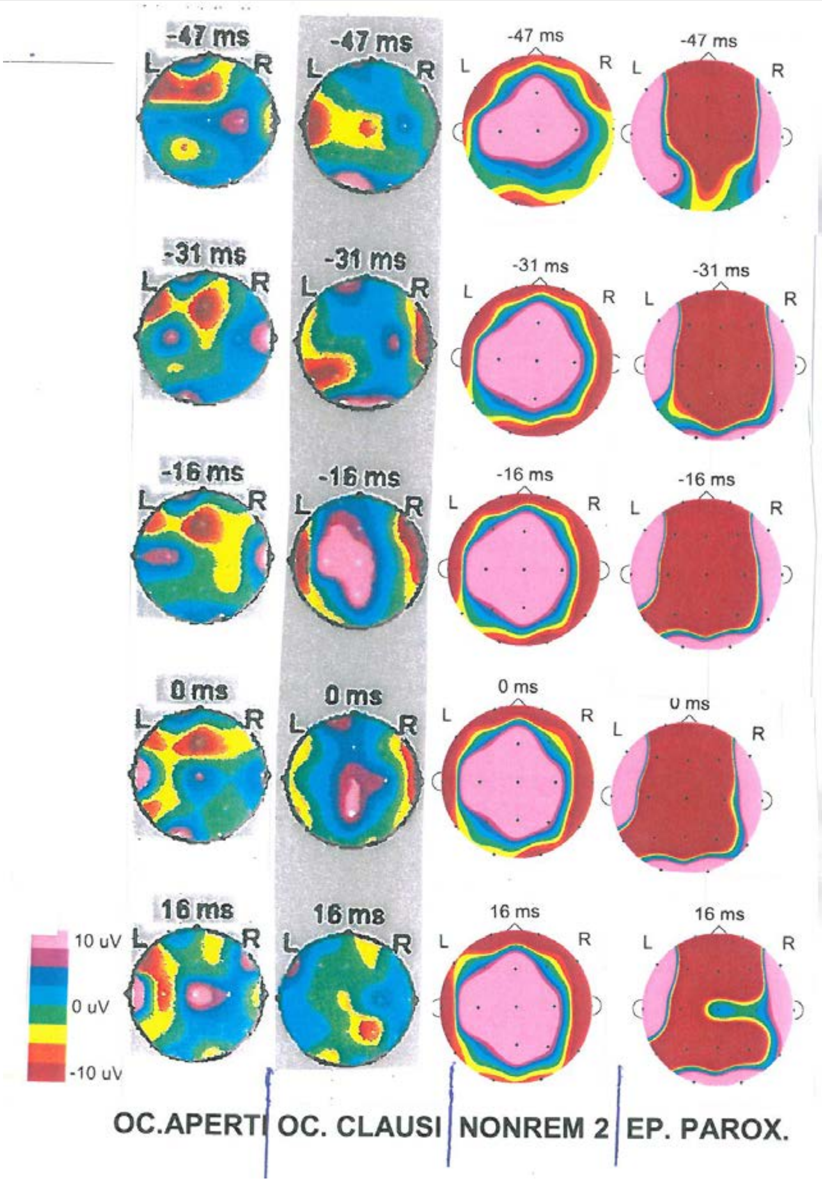

Fig. 5. Examples of amplitude analysis of the EEG curve during different states: oc. aperti – open eyes; oc. clausi – closed eyes; moderately deep sleep with a slow theta activity – NONREM 2; ep. paroxysmus – absence. Very apparent are the growing areas of maxims during different states (from left to right) that represent not only different synchronization and simplification, but also substantial difference in the work mode of thalamocortical system.

The peaceful vigilance, relaxing, or rather "empty meditation" with a "regular alpha" activity in the EEG can be described as attractor. The EEG has periodicity, even though not very regular. Every second-segment of the curve can contain alpha, but this alpha has always different shape. These differenced cannot be recognized by the naked eye; but if the EEG spectrum analysis is done, we can see that the spectrograms are never identical, but may be repeated with an irregular period – they are fundamentally pseudo-periodical and pseudo-identical. In the states of restlessness or during REM sleep, the instabilities in the brain activity are quite great; but if they do not deviate into pathological forms such as psychosis or epileptic seizure, they can be described as fractal behavior. However, it is fundamental that every attractor is fractal but not every fractal is an attractor.

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