

## To Live Longer with a Better Quality of Life through Coordination Dynamics Therapy Especially in Patients with Severe Brain Injury and Brain-Cancer

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### ABSTRACT

It is shown that three patients, with very severe brain injury and given up by school medicine, could reach a qualified life when coordination dynamics therapy (CDT) was administered to them for 10 to 20 years with 15 to 30 h training per week. They will live longer with a better quality of life than other brain injured patients who did not obtain optimal therapy for years, because a rather healthy brain can better control the regulatory processes of the body. The two young patients became able to finish the university. Benjamin learned to run 100 m in 14 s and Sotiris re-learned to drive a car. At an age of 31 and 34, respectively, they could exercise on a special CDT device in a power range what only athletes can manage. The rather healthy 78-year-old author, following 10 years of CDT with 15 h therapy per week after malign cancer treatment, could compete with the recovered young men. The missing power he compensated by a better coordination between arm and leg movements and upstream between neuron firings. The older of the three patients, who suffered at an age of 55 a very severe cerebrum and cerebellum injury and obtained CDT for more than 20 years, is still rather healthy and enjoys life at an age of 80. All three patients had a hopeless prognosis after the traumatic brain injury, but recovered strongly through the efficient, intensive and long-lasting movement-based learning therapy. CNS function improvements were quantified in the patients and the author by single values of the coordination dynamics.

On the basis of such tremendous progress in brain repair, the organ donation of brain-dead humans is discussed. Because there is strong interest to get more organ donors and with a long-lasting movement-based learning therapy no money can be earned, but money can be earned with organ transplantation, there exists the possibility that little effort is undertaken to keep patients alive in cases of very severe brain injuries. In brain cancer treatment, the brain can be repaired following the operation, growth of tumor cells inhibited and hypertension reduced simultaneously through CDT.

**Keywords:** Human neurophysiology, Electrophysiology, Repair physiology, Coordination dynamics therapy, Fountain of youth, Severe brain injury, Brain death, Organ donator, Brain-cancer treatment

### INTRODUCTION

#### The dream of the fountain of youth

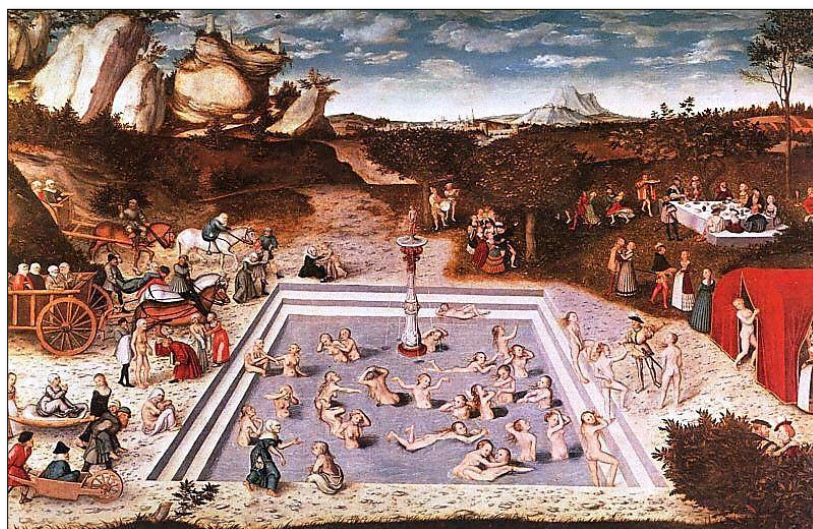
Many generations dreamt of a “Jungbrunnen” (fountain of youth) to become young and healthy again. The famous painter Lucas Cranach had pictured such a “Jungbrunnen”. In his painting, the elderly people enter the “fountain of youth” one side and leave it young and healthy on the other side (**Figure 1**). Such a dream cannot become reality by using coordination dynamics therapy (CDT). However, it is possible to partly reduce the biological age through a repair/improvement of central nervous system (CNS) functioning. This special movement-based learning therapy improves the fitness of patients and healthy people. But the improvement of wellbeing goes much deeper into health being than fitness because there is learning transfer from movements to

vegetative, cognitive and psychological functions. Since the CNS is involved in nearly all body functions, its improvement will lead to a general health improvement. It seems possible to live longer with a better quality of life by 10 to 20 years via CDT which holds for patients with nervous system injuries and healthy aging women and men.

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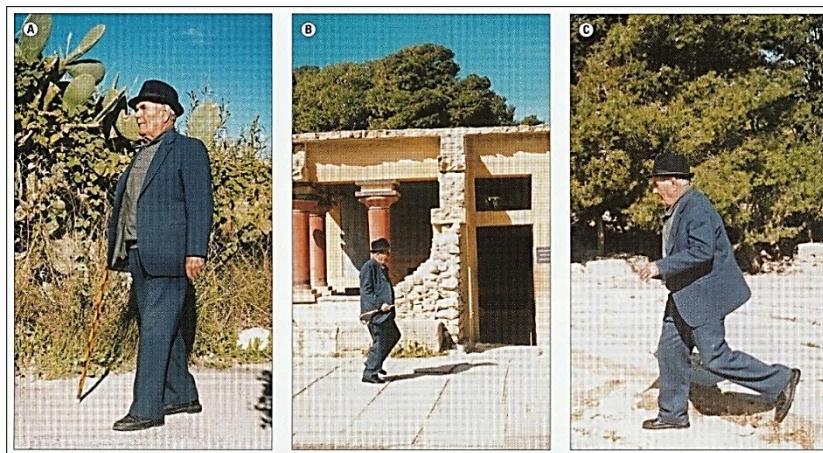
**Figure 1.** The fountain of youth painted by Lukas Cranach (Der Jungbrunnen von Lukas Cranach).

**Improvement of health in different diseases through CDT**

It would be difficult to organize a research project for 20 years to prove that the movement-based learning therapy CDT can increase your life expectation time by 10 to 20 years. Therefore, different case reports are used to support the claim that it is possible to live longer with a better quality of life.

It has been shown that CDT can improve or repair CNS functioning after stroke [1] (**Figure 2**), traumatic brain injury [2,3], spinal cord injury [4,5,6,7], cerebellar injury [8], cerebral palsy [9], hypoxic brain injury [10], in Parkinson’s disease [11,12], spina bifida (myelomeningocele) [13] and scoliosis [14]. Speech had been induced and improved in a patient with severe cerebral palsy [15] and a permanent coma patient [16].

Urinary bladder functions were repaired in patients with spinal cord injury [7,15]. In patients with cancer, especially breast cancer, cancer growth could be inhibited via CDT [17]. A partial repair of the brain could be achieved in a permanent coma patient who lost approximately 50% of the brain. He recovered from coma through 4 to 5 years of CDT with 20 h therapy per week and relearned to speak following 6 years of CDT [16]. A transient regeneration of the spinal cord could be achieved in a 9.5 years old girl through CDT [18]. Cardio-vascular performance could be repaired in a coma patient [19]. Details of human neurophysiology and movement-based learning theory, to repair the neural networks of the human CNS, have been published in three books [15,19,20]. A review of CDT has been published recently [21].



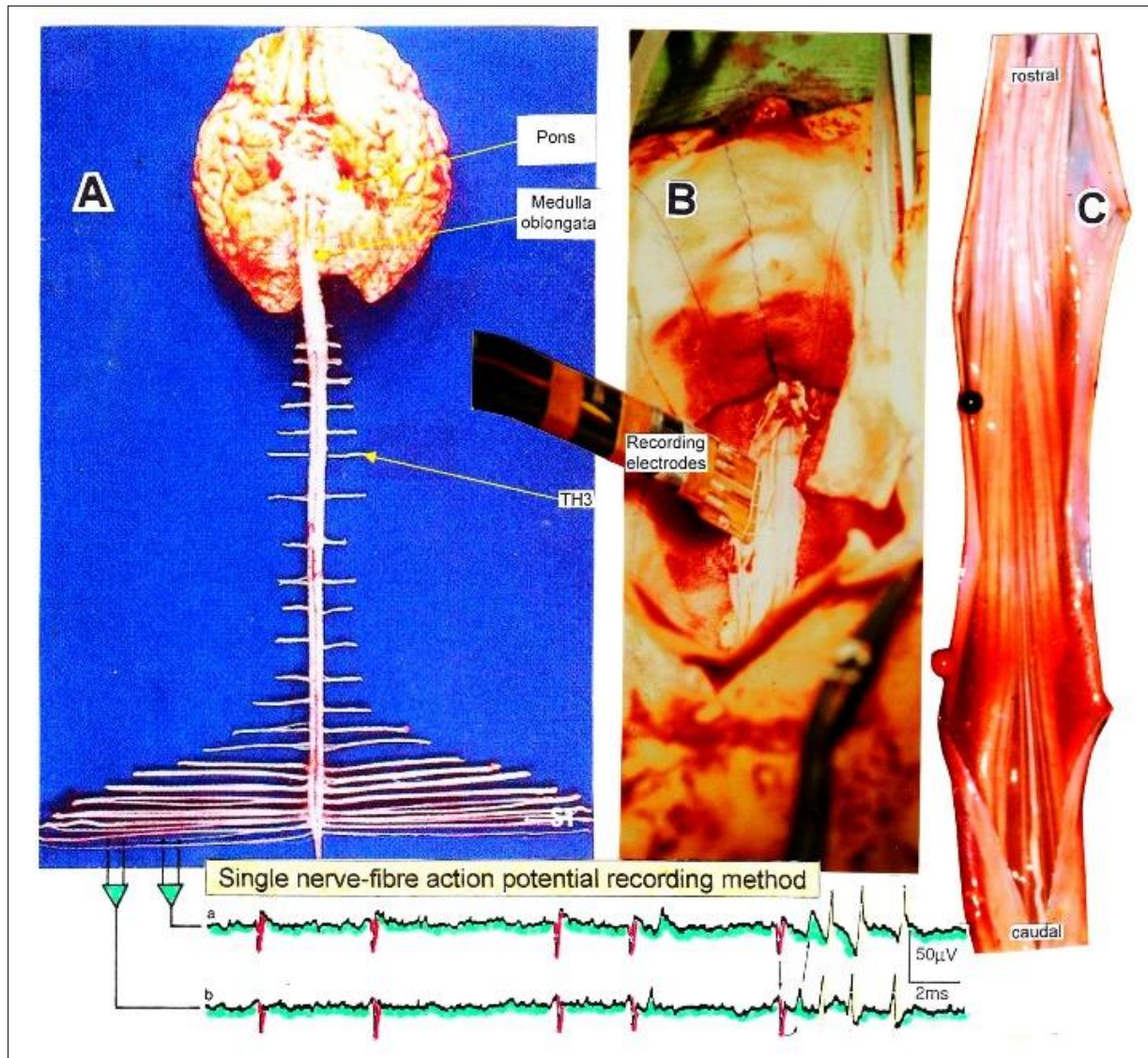
**Figure 2.** 82-year old patient after stroke. A) Patient is using the stick during walking. B,C) Via CDT the patient can run again over Minoan culture (Knossos, Greece).

## METHODS

### Single-nerve fiber action potential recording method

The scientific basis for CDT [21] could be developed with the single-nerve fiber action potential recording method

[22] (Figure 3) and using other methods and different strategies.



**Figure 3.** Layout of the recording of single-nerve fiber action potentials to analyze the self-organization of neuronal networks of the human CNS under physiologic and pathophysiologic conditions. By recording with two pairs of platinum wire electrodes (B) from sacral nerve roots (cauda equine, C) containing between 200 and 500 myelinated nerve fibers, records were obtained in which single-nerve fiber action potentials (APs) were identified from motoneurons (main AP phase downwards) and afferents (main AP phase upwards). By measuring the conduction times and with the known electrode pair distance of 10 mm, conduction velocity distribution histograms were constructed in which the myelinated nerve fiber groups larger than 4  $\mu\text{m}$  could be characterized by group conduction velocity values.

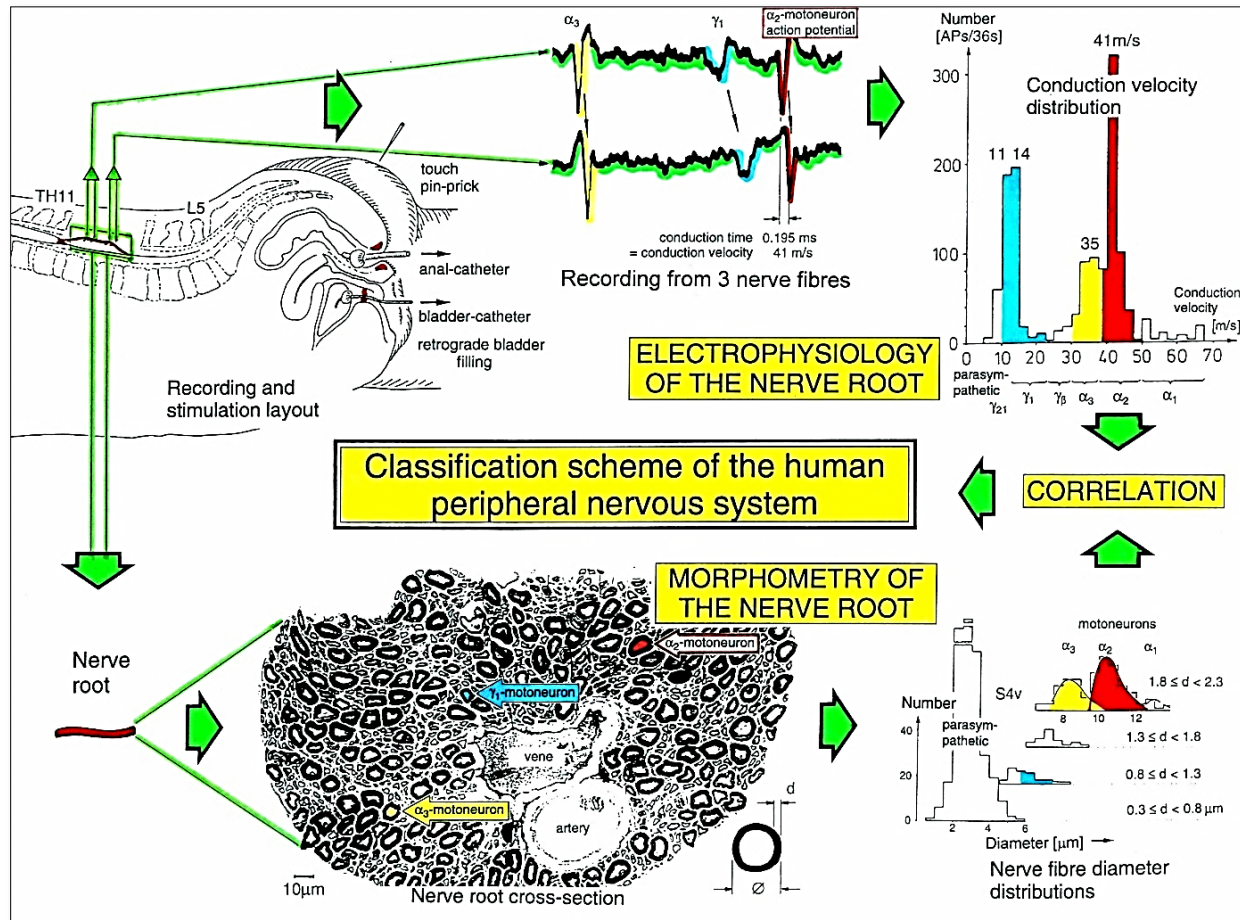
### Classification of human peripheral nerve fibers

By correlating the peak values of the velocity distributions with those of the diameter distributions obtained for the same root, a classification scheme was developed for the human peripheral nervous system

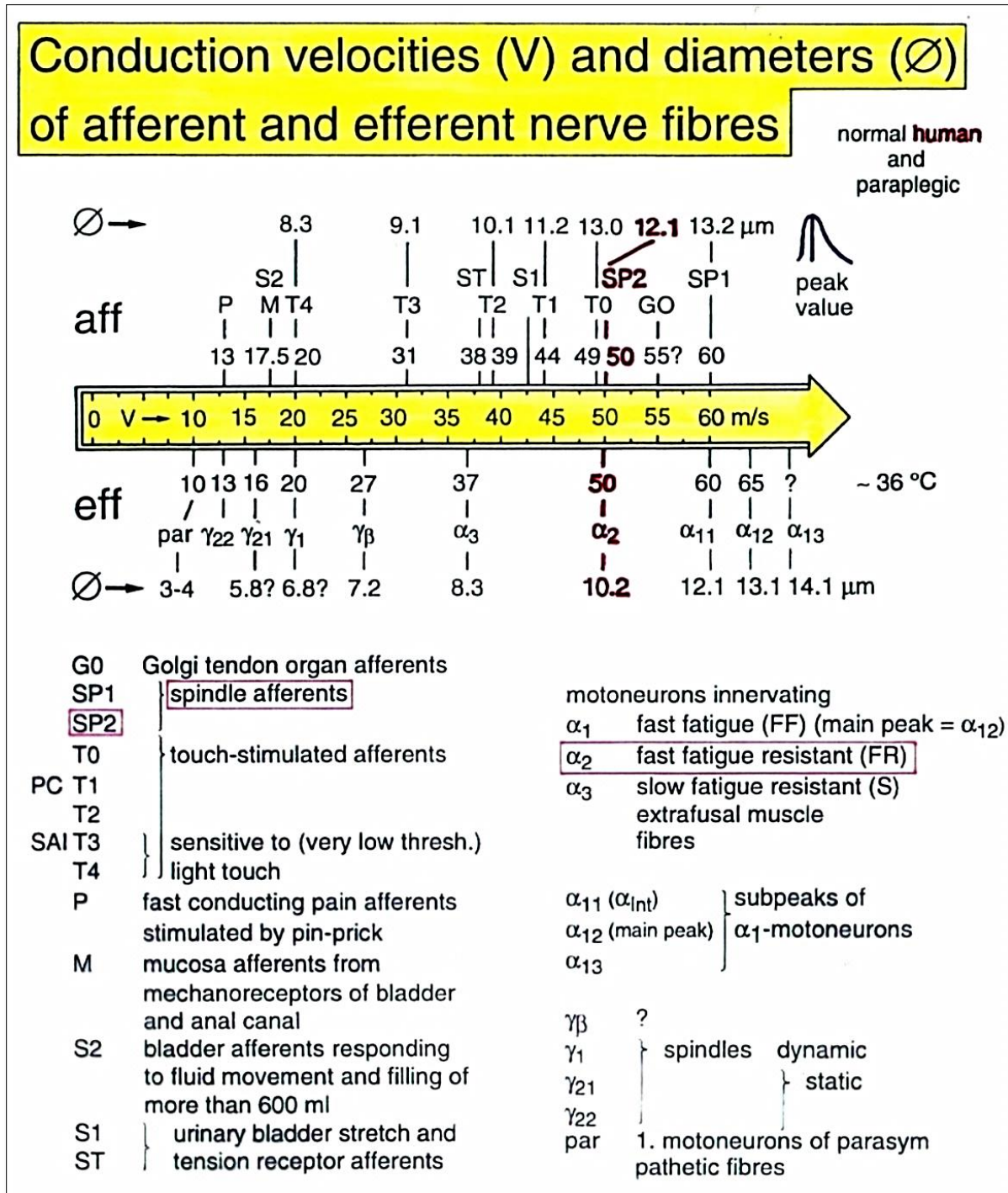
(Figures 3M and 3N) [23]. The group conduction velocities and group nerve fibre diameters had the following pair-values at 35.5°C: Spindle afferents: SP1 (65ms<sup>-1</sup>/13.1  $\mu\text{m}$ ), SP2 (51/12.1); touch afferents: T1 (47/11.1), T2 (39/10.1), T3 (27/9.1), T4 (19/8.1); urinary

bladder afferents: S1 (41 ms<sup>-1</sup>/-), ST (35/-);  $\alpha$ -motoneurons:  $\alpha_{13}$  (-/14.4),  $\alpha_{12}$  (65 ms<sup>-1</sup>/13.1  $\mu$ m),  $\alpha_{11}$  (60<sup>?</sup>/12.1)[FF],  $\alpha_2$  (51/10.3)[FR],  $\alpha_3$  (41/8.2)[S];  $\gamma$ -motoneurons:  $\gamma_\beta$  (27/7.1),  $\gamma_1$  (21/6.6),  $\gamma_{21}$  (16/5.8),  $\gamma_{22}$  (14/5.1); preganglionic parasympathetic motoneurons: (10 ms<sup>-1</sup>/3.7  $\mu$ m). The designations of the symbols are given in **Figure 3N**.

With respect to electrical stimulation, it was found that the primary spindle afferents likely have the lowest threshold upon electrical nerve root stimulation, followed by  $\alpha_1$ -motoneurons (FF), secondary muscle spindle afferents,  $\alpha_2$ -motoneurons (FR),  $\alpha_3$ -motoneurons (S),  $\gamma_\beta, \gamma_1$  (dynamic),  $\gamma_{21}$  (static),  $\gamma_{22}$  (static), and parasympathetic motoneurons.



**Figure 3M.** Development of a classification scheme for human peripheral nerve fibers. Conduction velocities (V) and nerve fiber diameters ( $\emptyset$ ) of afferent and efferent nerve fiber groups in normal humans and in patients with a traumatic spinal cord injury for 0.5 to 6 years.



**Figure 3N.** Classification scheme for human peripheral nerve fibers. Conduction velocities (V) and nerve fiber diameters (∅) of afferent and efferent nerve fiber groups in normal humans and in patients with a traumatic spinal cord lesion for 0.5 to 6 years. The splitting of the α<sub>1</sub>-motoneurons into the 3 subgroups, α<sub>11</sub>, α<sub>12</sub>, α<sub>13</sub>, has not yet been confirmed.

As we can now measure the natural impulse patterns in identified nerve fibers, generated by certain single receptors in the periphery, which run into the spinal cord (CNS) and those patterns which leave the cord in ensembles of single fibers simultaneously, it becomes

possible to analyze the integrative properties of the largely unchanged CNS in brain-dead humans (HTs) and following CNS injury in patients at the neuron level. This also means that the changes in function, caused by the CNS injury, can be identified. The use of this new

electrophysiological recording technique brought new understanding of the functioning of the human CNS and has allowed for much greater opportunity in identifying techniques for its repair.

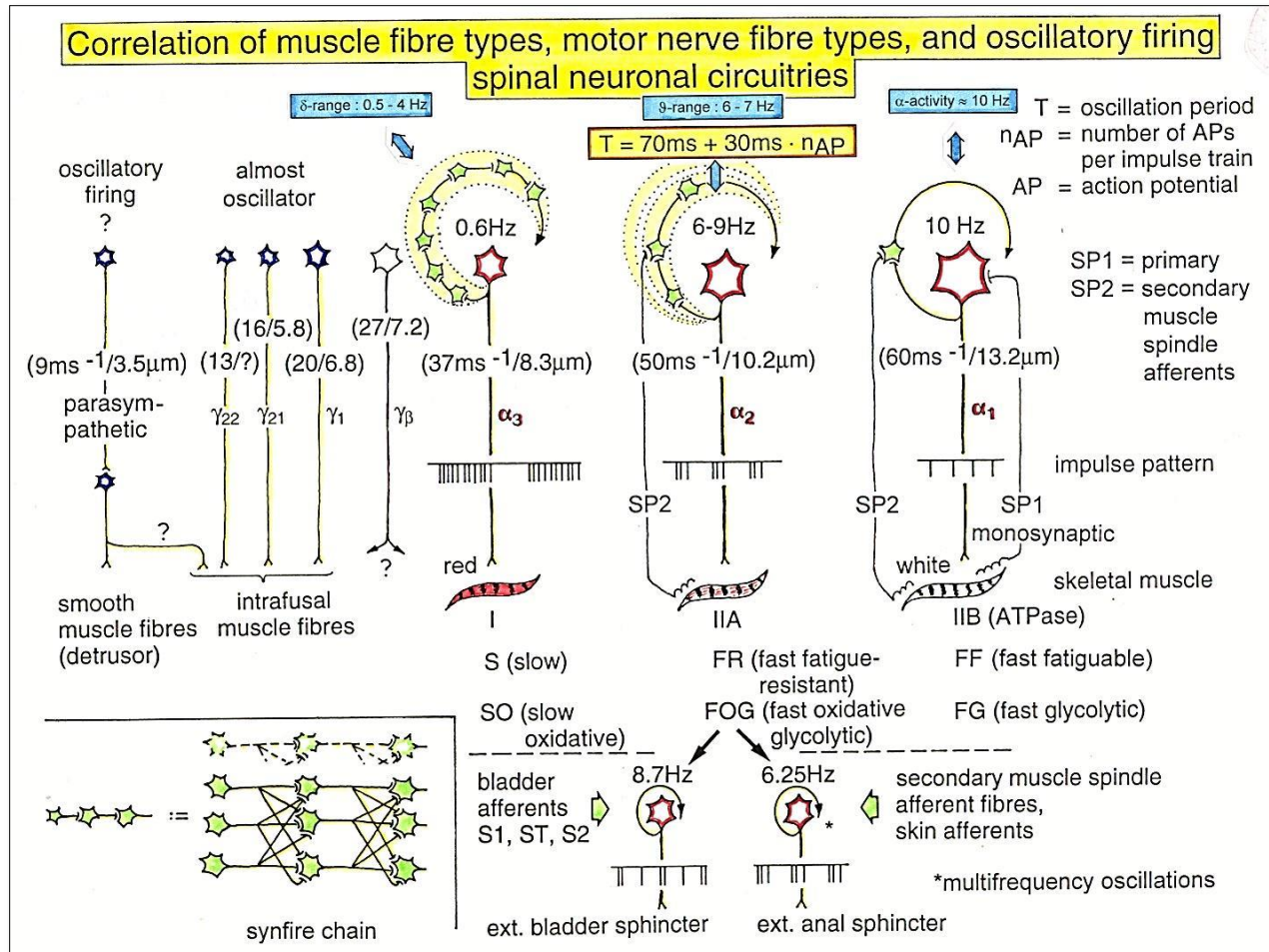
Two important findings of CNS self-organization with respect to repair are the oscillatory firing of premotor spinal oscillators of which the motoneuron is most likely a part (**Figure 3Q**) and the phase and frequency coordination among neuron firings (**Figures 3P, 3R**). Following CNS injury, the phase and frequency and the oscillatory firing of the sub-network oscillators become impaired and have to be repaired. Apart from the improvement of phase and frequency coordination and the oscillatory firing of sub-networks, other brain parts have to take function over by plasticity from the damaged CNS parts during repair. The phase and frequency coordination is improved when the patient exercises on the special CDT device (**Figure 14**, inset) and the premotor spinal oscillators are partly repaired to fire more rhythmically when jumping on spring-board (**Figure 5B**) what a coma patient cannot perform by himself. Further, automatisms like crawling, walking and running and other movements have to be trained, so that other brain parts can take functions over by plasticity through movement-based learning.

### Premotor spinal oscillators

Typical firing patterns of motoneurons can be observed when motoneurons are activated with increasing strength of adequate afferent input. With low afferent input, the motoneurons fire occasionally. With increasing input, they fire intermittently in an oscillatory manner and then continuously in an oscillatory manner. The demonstration that neurons of the CNS, in this case motoneurons, can fire both in an oscillatory manner and non-oscillatory manner is very important for the understanding of the functioning of the human CNS. To describe the functioning of the CNS merely by reflex pathways and loops or coupling of rigid oscillators (of cellular or network origin) is in contradiction to empirical human data, namely that premotor spinal oscillators self-organize as was concluded from measurements of simultaneous natural impulse patterns of afferent and efferent fibers. In what follows, we shall concentrate mainly on the oscillatory firing of motoneurons, which takes place for high activation. In this high activation mode, they can also be used as a reference basis when defining phase relations and thus phase and frequency coordination can

be measured among neuron firings. For high and rather constant afferent input it was found that  $\alpha$ -motoneurons fire repeatedly with impulse trains according to their type (**Figure 3O**). The  $\alpha_1$ -motoneurons (FF) fire rhythmically at around 10 Hz (range 8 to 20) with an impulse train consisting of 1 action potential (AP);  $\alpha_2$ -motoneurons (FR) fire at approx. 6 to 9 Hz with 2 to 5 APs per impulse train, and  $\alpha_3$ -motoneurons (S) fire with a frequency in the range of 1 Hz and with long impulse trains consisting of up to 40 APs (and more). The rhythmic firing patterns of  $\alpha$ -motoneurons are probably generated by local neuronal networks of the spinal cord since oscillatory firing can be recorded from motoneurons of the disconnected spinal cord. It may be that the motoneuron is a part of the spinal oscillator. The oscillation period (T) is roughly related to the number of action potentials (APs) per impulse train ( $n_{AP}$ ), and this can be expressed by the formula:  $T = 70 \text{ ms} + 30 \text{ ms} \cdot n_{AP}$ . A typical premotor  $\alpha_2$ -oscillator fires with 3 APs every 160 ms ( $T = 70 \text{ ms} + 30 \text{ ms} \cdot 3 = 160 \text{ ms}$ ), and can change its firing pattern to 2 APs every 130 ms for less activation or to 4 APs every 190 ms for higher activation.

The  $\alpha_1$ -oscillators respond very dynamically, but have little oscillator network properties. Their firing is absolutely correlated to the firing of primary spindle afferent fibers. The  $\alpha_2$ -oscillators respond less dynamically, have strong oscillatory properties and self-organize by the adequate afferent input patterns from several kinds of receptors including secondary muscle spindle and urinary bladder afferents. The behavior of  $\alpha_3$ -motoneurons is more static and their input is polymodal. The dynamics of responding to inputs increases from  $\alpha_3$  to  $\alpha_2$  to  $\alpha_1$ -oscillators in accordance with the dynamics of the 3 muscle fiber types the  $\alpha$ -motoneurons innervate. The slow (S), medium fast (FR) (fast fatigue-resistant) and fast contracting muscle fibers (FF) (fast fatigable) have their own corresponding premotor networks in the spinal cord, namely that in which the  $\alpha_1$ ,  $\alpha_2$  and  $\alpha_3$ -networks are integrated in (**Figure 3O**).



**Figure 30.** Correlation of muscle fiber types, motor nerve fiber types, and oscillatory firing spinal neuronal networks, based on histochemical, morphological and physiological properties. This figure provides a simplified correlation between muscle fiber, motoneuron and sacral oscillator types. No additional subtypes have been included. The existence of  $\alpha_1$ -motoneuron (FF) oscillators firing at 10 Hz has been predicted and they have been identified in paraplegics.  $\alpha$  = motoneuron,  $\gamma_1$ ,  $\gamma_2$  = dynamic and static fusimotors, parasympathetic = parasympathetic preganglionic motoneuron. S1, ST, S2 = stretch, tension and flow receptor afferents of the urinary bladder.

**Phase and frequency coordination**

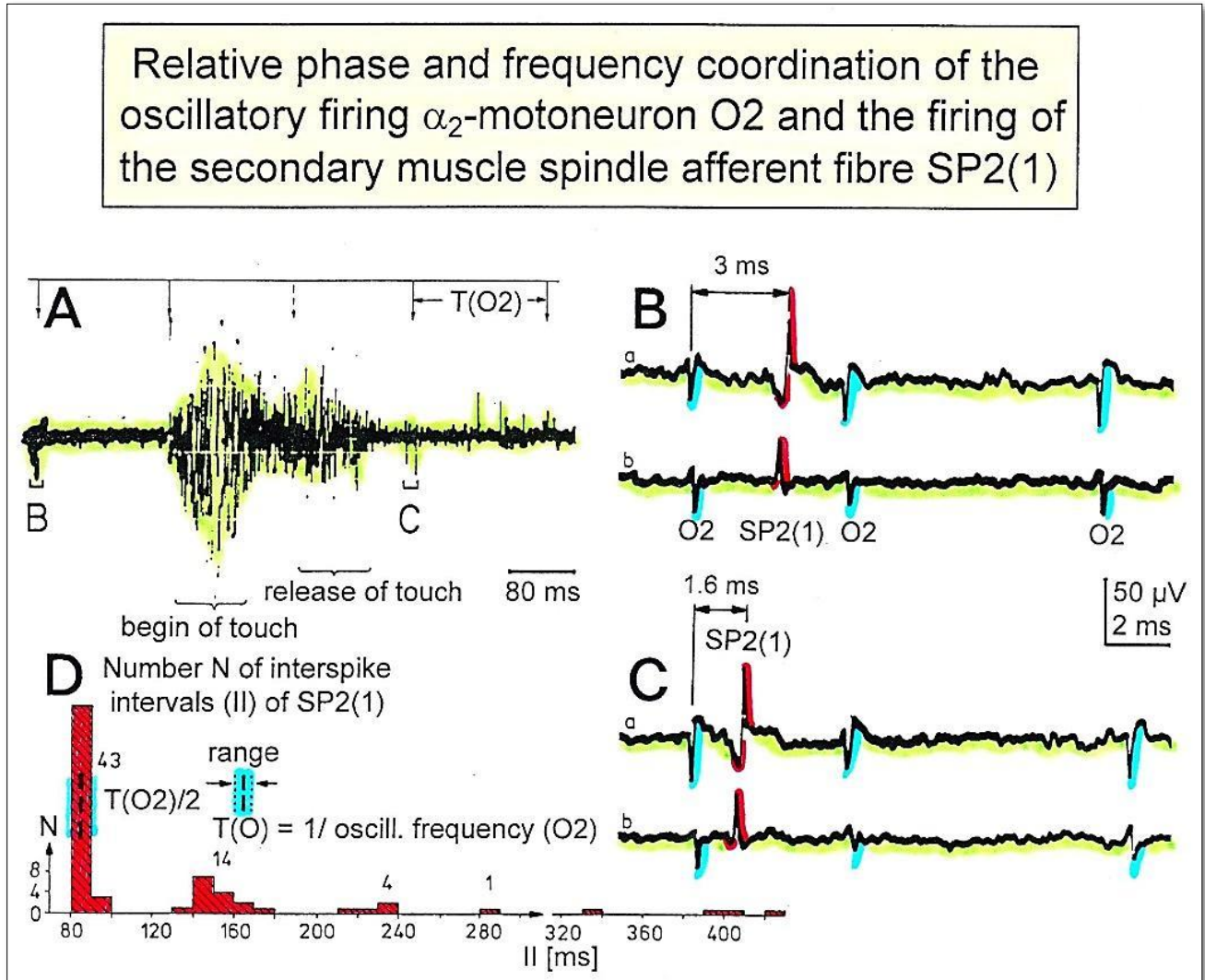
Relative phase and frequency [34] coordination between the APs of an oscillatory firing \*2-motoneuron (O2) and a secondary muscle spindle afferent fiber SP2(1) can directly be seen in the original recordings with the single-nerve fiber action potential recording method in **Figure 3P**. The firing of the oscillator and the sweep pieces which are shown time-expanded are indicated at the summary trace. **Figure 3P (B, C)** shows the AP-impulse train of oscillator O2 in connection with one of its driving spindle afferent AP. Because of the duration of the phase relation of around zero milliseconds between the firing of the driving SP2(1)-fiber (firing mostly every 80ms) and the impulse train of the oscillatory firing motoneuron O2 ( $T(O2) \approx 160ms$ ), the SP2(1)-fiber AP (every second AP) appeared at a similar time as the impulse train of the oscillatory firing motoneuron. Because the AP of the

spindle afferent fiber had a characteristic waveform, it was easy to extract its impulse pattern from the summed impulse traffic of this S4 dorsal root. During touch-induced skin afferent activity (**Figure 3P**), the activities of the motoneuron and the spindle afferent fiber were covered by the skin afferent activity. After the cessation of the skin afferent activity the afferent and efferent APs were found again at their expected time positions of the regular firings. The phase coordination between the firings of the oscillatory firing motoneuron O2 and the secondary muscle spindle afferent fiber SP2(1) at the time when records B, C were taken, was 1.6 ms (3 ms - 1.4ms, **Figure 3P-B, C**). In 'D', the relative frequency coordination between the firings of the SP2(1)-fiber and the impulse train of the oscillator is indicated. For the time period evaluated, the correlation between the firing

of the motoneuron and the spindle afferent fiber was in the range of between 3 and 5 ms (D).

The fact that neurons fire in a relatively coordinated way of up to a few milliseconds, which becomes impaired following injury, is used for re-organizing the injured

CNS by re-learning phase and frequency coordination between neuron firings again when exercising movements coordinated with an exactness of up to a few milliseconds, by using the special coordination dynamic therapy device, i.e. by instrumented supervised phase and frequency re-learning (Figure 4).

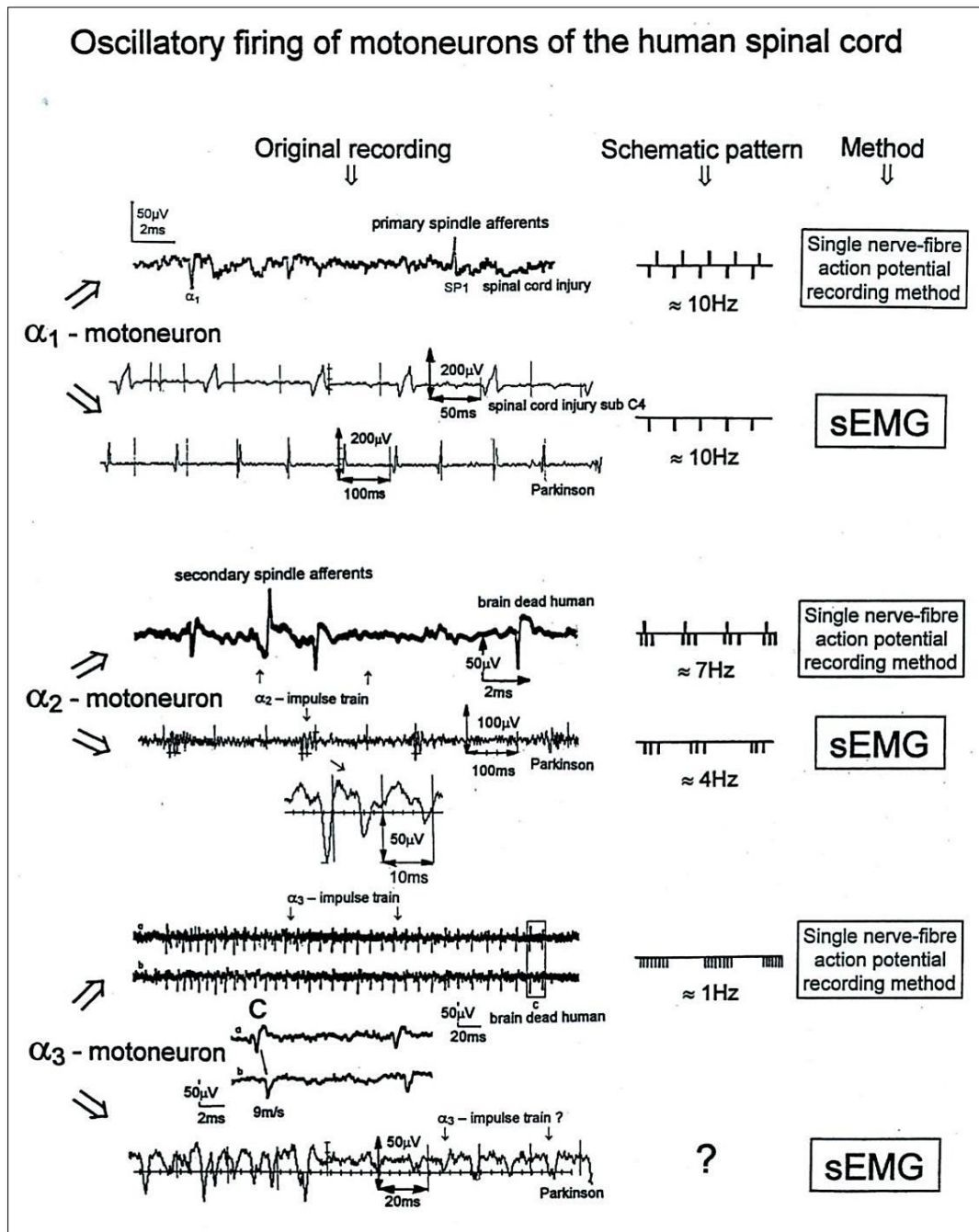


**Figure 3P.** Time relation between the occurrence of the action potentials (APs) of oscillatory firing  $\alpha_2$ -motoneuron O2 and the firing of the secondary muscle spindle afferent fiber SP2(1). Brain-dead human HT6. S4 dorsal root recording. **A.** Overall view of the used sweep piece; only trace "a" shown. Four oscillation cycle periods of motoneuron O2 are indicated (T(O2)). The APs of the impulse trains can be recognized only partly, because of the slow time base and poor digitalization. One impulse train (dashed arrow) is lost in the touch stimulated activity, which consists of a touch (large overall activity) and a release part (lower overall amplitude). **B,C.** Sweep pieces from A, time stretched. In B, motoneuron impulse train APs are marked O2, spindle afferent APs are marked SP2(1). Note that the APs of the spindle afferent fiber are not time-locked to the first AP of the impulse train of the rhythmically firing motoneuron (relative phase coordination). Digitalization 4 times better than in A, but still rather poor, as can be seen from the low amplitudes of the motoneuron APs on trace "b" in C. **D.** Occurrence of interspike intervals of the secondary muscle spindle afferent fiber SP2(1). The numbers give the amount of IIs in each distribution peak. The oscillation period of motoneuron O2 (and the range of variation) and the half period are indicated by short dashed lines. Note that the IIs of fiber SP2(1) are very similar to the oscillation period (or the half of it) of  $\alpha_2$ -motoneuron O<sub>2</sub> (relative frequency coordination).

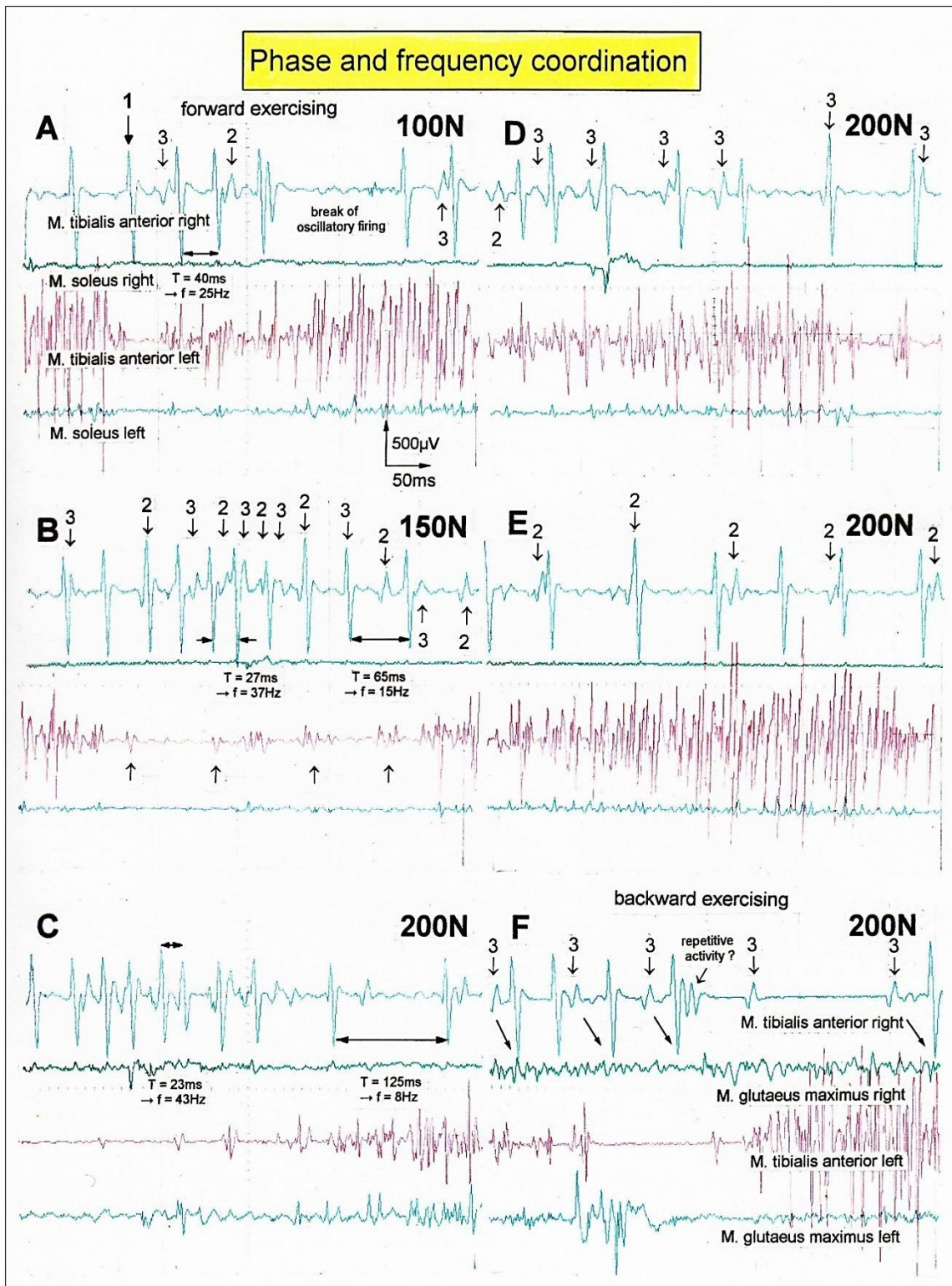


To make this important phase and frequency coordination among neuron firings [24] also non-invasively visible, recordings with the single-nerve fiber action potential recording are correlated with those of the surface

electromyography (sEMG) (Figure 3Q). The phase and frequency coordination among neuron firings/motor units can now nicely be observed in suitable patients (Figure 3R).



**Figure 3Q.** Oscillatory firing patterns of  $\alpha_1$ ,  $\alpha_2$ , and  $\alpha_3$ -motoneurons recorded from motoneuron axons with the single-nerve fiber action potential recording method and by surface electromyography (sEMG) from FF, FR, and S-type motor units. The left panel shows original recordings, the middle panel the schematic patterns; the recording methods are indicated on the right side. The recordings were taken from patients with spinal cord injury and Parkinson’s disease and from brain-dead humans.



**Figure 3R.** Recording of phase and frequency coordination between oscillatory firing motor units (1, 2, 3; FF-type) by surface EMG during the generation of a motor program when exercising on the special coordination dynamics therapy device at loads increasing from 100 to 200N. Oscillation periods (T) and oscillation frequencies (f [Hz]) of oscillatory firing motor unit 1 are partly indicated. In 'F', some coordination's between motor unit '3' and '1' are marked.

### Coordinated firing of neurons, their impairment and repair by learning

In every CNS injury, surgery, degeneration, malformation or aging the phase and frequency coordination of neuron firing becomes impaired and disturbs or destroys CNS self-organization. Also, the organization of sub-networks and their communication becomes impaired. The impairment of the sub-network premotor spinal oscillator by injury can be nicely measured by the variation of the oscillation frequency. In rather physiologic cases, such as in brain-dead humans, the premotor  $\alpha_2$ -oscillators fire rhythmically with a certain Eigen-frequency. Following spinal cord injury, the oscillators lose their Eigen-frequency to some extent and fire at many different frequencies.

The impaired coordination between nerve cells and arm and leg movements following injury can be improved especially by exercising on the special CDT device, which is very precisely manufactured (**Figure 4**). **The exactness of the device guarantees that the**

**coordinated arm and leg movement induced afferent input can teach the neurons of the CNS to improve their coordinated firing up to within a few milliseconds.** Since the neurons work as coincidence and more widely as coordination detectors (**Figure 27**), this improved coordinated firing improves for example the communication among nerve cells and neural sub-networks (especially between networks across an injury site as for example in spinal cord injury) because the threshold of neuron excitation is reached earlier. The training of phase and frequency coordination via coordinated arm, leg and trunk movements improves not only the self-organization of the corresponding sub-networks but also the functioning of the CNS neural networks in general by learning transfer [31]. Some motor and other patterns re-appear upon this improved coordination at the neural and movement level. For example, a child with cerebral palsy learned to speak following exercise on the special device through learning transfer [15].

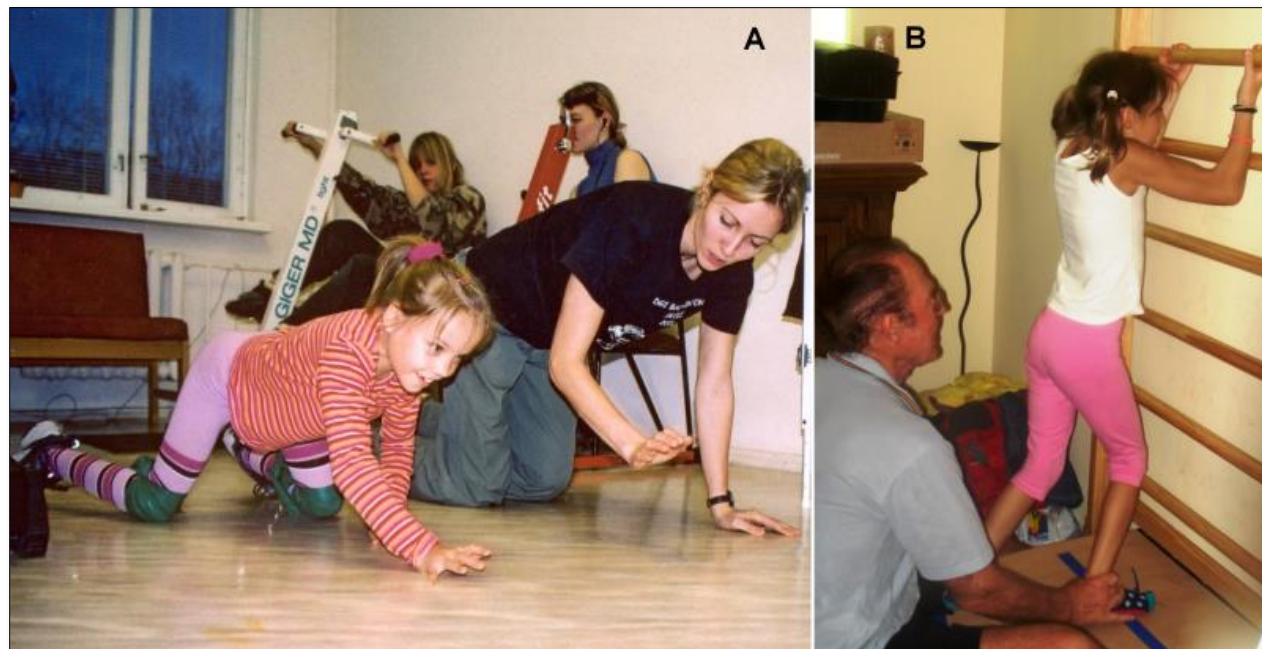


**Figure 4.** Recording of the coordination dynamics when exercising on a special CDT device of a 72-year-old patient after the removal of an anaplastic oligodendroglioma WHO grade III and radiation therapy. It is exercised on the special CDT device to repair the brain due to injury, caused by the operation, to inhibit cancer growth and to improve hypertension simultaneously to live longer with a better quality of life.

### Other parts of the CNS have to take functions over through plasticity

The improvement of phase and frequency coordination is not sufficient for repair. When large parts of the brain are lost other parts have to take function over by the so-called

plasticity. This can be achieved when patients are training automatisms and other movements where the whole brain and spinal cord are involved so that other CNS part can learn to take function over. Such movements are creeping, crawling (**Figure 5A**), walking, running and jumping (**Figure 5B**) and other patterns.



**Figure 5. A.** Trot gate crawling of a cerebral palsy girl in interpersonal coordination with a therapist. The crawling performance of the therapist is not optimal. The right arm is leading with respect to the left knee. Also, the crawling performance of the patient is not optimal; the knees are too much apart. **B.** Ten-year-old patient Nefeli with an incomplete spinal cord injury during jumping on springboard, supported by the author. With the right small finger, the author is keeping the foot in a physiologic position to improve the afferent input to the CNS during jumping.

When training complicated coordination's in the deepness of complexity of CNS organization, variability is mainly trained. With the automatisms crawling, walking and running mainly the stability of CNS organization is trained. For physiologic CNS functioning there is a fine balance between variability and stability of neural network organization needed. The progress in CNS repair is the human repair physiology and not a miracle movement or device.

#### **Epigenetic regulation for repair by movement-based learning at the neuron level [35-37]**

1. Repair depends on learning and memory formation, mediated or supported by epigenetic mechanisms. Epigenetics is the interplay between genes and the environment resulting in phenotype and epigenetic landscape.

2. Epigenetic mechanisms like DNA methylation are probably sensors for movement-based learning and memory formation and fine modulators of neurogenesis in the adult CNS with CDT (**Figure 6**).

3. The epigenome consists of non-coding RNA and chromatin, a proteinaceous matrix surrounding DNA. The dynamic interactions of post-translationally modified chromatin proteins, covalently modified cytosines inside DNA and non-coding RNA define the complex pattern of gene expression beyond the four bases of DNA.

4. The hippocampus plays an essential role in learning and memory. In the hippocampus there exists a specialized form of neural plasticity, which is, the generation of new functional neurons from stem cells occurring throughout life. Adult hippocampal neurogenesis contributes to learning and memory formation.

5. New neurons [32] are important for learning and memory formation (besides functional reorganization), i.e. for increasing the rate of repair, for the following reasons:

a. The insertion of new neurons helps to store the memory of the same activity that led to the creation of the neuron.

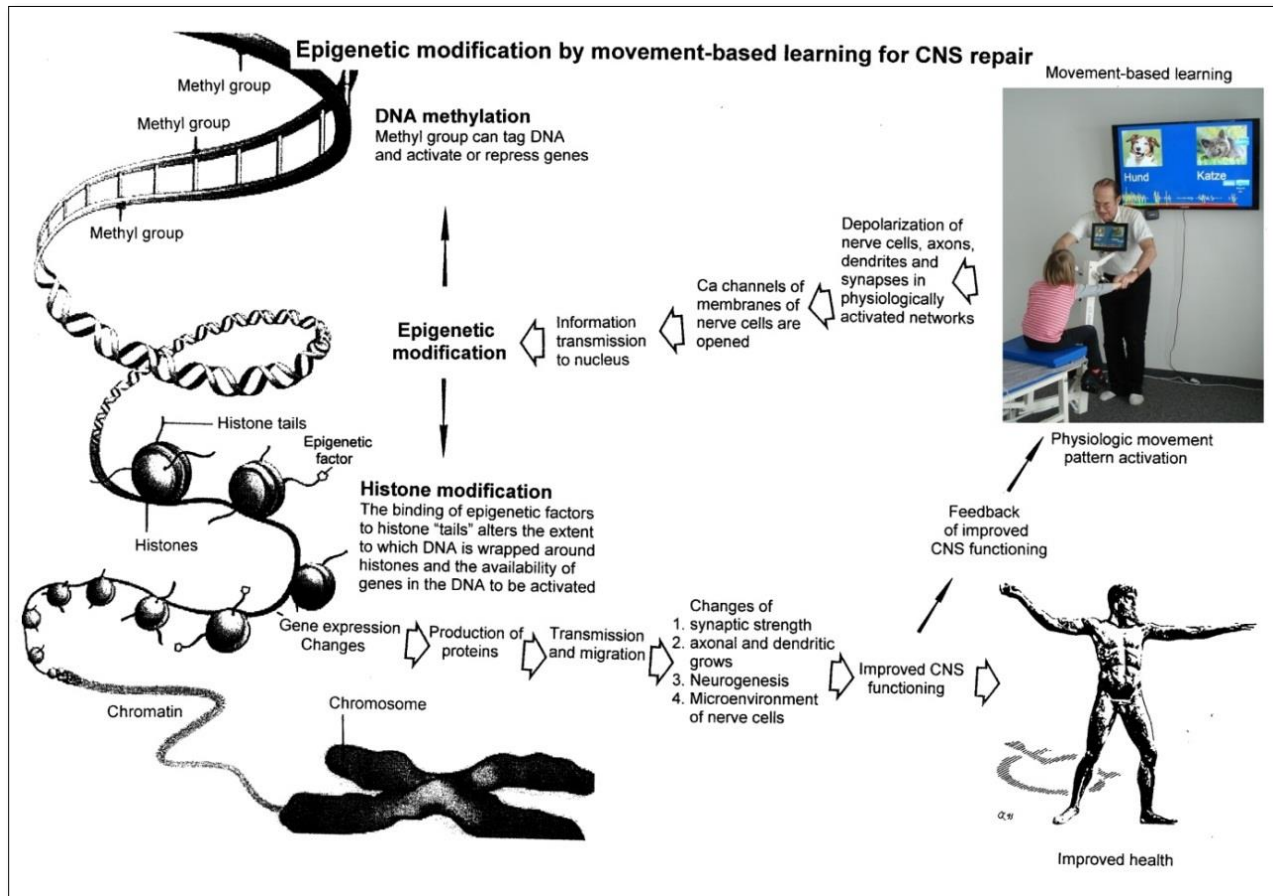
b. Activity-dependent neurogenesis enhances the learning of new memories and degradation and clearance of previously stored unwanted memories like spasticity, because the synapses, dendrites and axons can be devoted more fully to the newer memories. The old neurons with large and complex axon and dendritic trees are difficult to change. They can only be changed with sustained effort.

c. New neurons seem to improve the accuracy of relearned patterns (from model study [33]). This means that new neurons help to improve phase and frequency coordination of neuron firing and pattern stability.

d. The advantage of new neurons seems to be dramatically greater in networks that had been more

active and had been required to store more memories [33]. The advantage of neurogenesis for memory storage in heavily active networks is that it provides an increased

rate of repair if movement-based learning is administered aggressively and if different movements are trained.



**Figure 6.** Epigenetic regulation for repair by movement-based learning. CDT-induced stimulation of the pathways that regulate neural network repair is a proven therapeutic and preventive tool. Epigenetic mechanisms, stimulated by physiologic network activation, are likely key players within signaling networks, as DNA methylation, chromatin remodeling and small non-coding RNAs superfamilies’ are required for the fine-tuning and coordination of gene expression during neural network repair by learning. Since the nervous system is involved in nearly all body functions, CDT will improve health.

6. Specific natural network activity is required for multiple aspects of repair. Specific activity is essential for correct migration of interneurons and it also controls the development and repair of their axons and dendrites. During repair there is a specific requirement of network activity in shaping the cortical integration of specific neuronal subtypes. Newly build neurons are likely electrically active shortly after their birth and participate in the early network activity that contribute to circuit maturation during repair by CDT.

7. Specific activity is required for migration and maturation at several stages of repair. A break in CDT may invalidate the whole chain of repair events. Specific interneuron subtypes require activity for migration and morphological maturation at two distinct stages of

development [33]. Newly built neurons may even require specific activity for migration and maturation at several distinct stages of repair. During a break in CDT, the specific activity, required for neuron migration, maturation and network integration may not be supplied at one of these stages so that the chain of repair events is severed and the whole repair chain has to be started anew.

8. For optimal repair specific downstream and upstream activity is needed. Since coma patients cannot move by themselves, only the specific movement induced afferent input is available for repair. But since the movement induced afferent input during support by a therapist improved motor programs (**Figure 5B**), it is likely that the specific activity induced by the movement induced afferent input can to a certain extent also offer the specific

activation necessary for proliferation and migration of neurons and network maturation. Further, some automatisms like the blink or swallowing reflex are partly working and activate motor patterns.

9. Drug application may undermine repair. Altering the level of neuronal excitability within genetically targeted neurons from drug application, for example antiepileptic drugs may have profound consequences on multiple aspects of the repair of select types of neurons within a population of neurons, as well as their associated gene expression. The pain-killer 'Contergan', taken during pregnancy, changed gene expression and the babies were born without arms.

10. Excitation-neurogenesis coupling [33].

a. Excitation increases or decreases neuron production directly by excitation-neurogenesis coupling.

b. The excitation acts indirectly on the surrounding mature (hippocampal) cells through depolarization-induced release of growth factors.

c. Adult neurogenesis is enhanced by excitatory stimuli and involves Ca<sup>2+</sup> channels and NMDA receptors.

d. The Ca<sup>2+</sup> influx pathways are located on the proliferating stem/progenitor cells (NPCs), allowing them to directly sense and process excitatory stimuli. The Ca<sup>2+</sup> signal in NPCs leads to rapid induction of a proneural gene expression pattern.

11. Integrative coordinated movements have to be trained to allow functional reorganization and new nerve cell integration across very large distances. CDT has to activate injured and uninjured networks to enhance physiologic CNS functioning and learning transfer.

### Conclusion for optimal therapy according to the present stage of knowledge

If there is similarity between development and repair, animal (mice) data also hold in humans and the principles of neurogenesis of the hippocampus also hold in other parts of the brain, albeit to a much lesser extent, then the patient has to be trained at his limits (1) to induce substantial building of new nerve cells [32]. The treatment has to be continuously administered (2) to

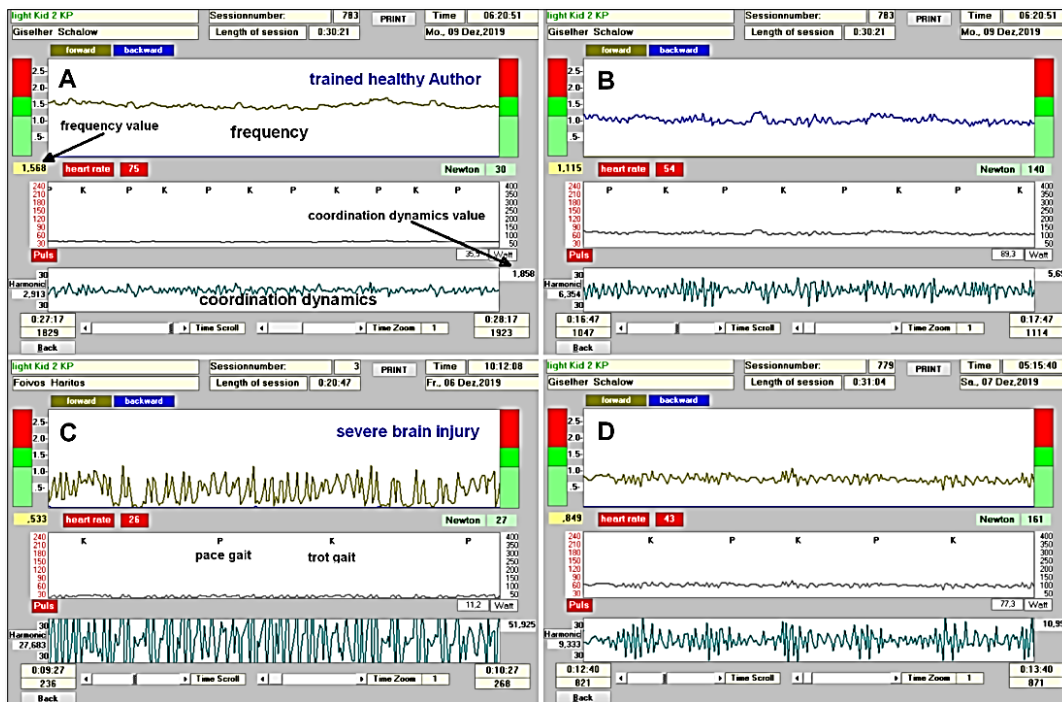
support all stages of repair at the progenitor level as migration, maturation and integration. The networks requiring repair have to be activated specifically (3) to generate repair-friendly, micro-environmental properties in the networks. No drugs should be administered that change neuron excitability (4). The exercises have to include coordinated arm, leg and trunk movements (if possible) to improve the impaired phase and frequency coordination [34] for CNS self-organization (5). The performed movements have to be as integrative as possible to reconnect distant brain parts and to induce learning transfer [31].

### Measuring of CNS repair and health improvement

Progress in CNS repair and improvement of health has to be measured. This is achieved non-invasively in this report by measuring coordination dynamics, movements and blood pressure. Coordination dynamics measurements are based on the System Theory of Pattern Formation [25]. Through pattern change the quality of CNS functioning can be measured, which is realized when exercising on the special CDT device and measuring the arrhythmicity of turning during the continuously changing patterns between pace and trot gait (**Figure 4**).

**Figure 7** shows such coordination dynamics measurements of the aging healthy author (A, B, D) in comparison to those of a patient with a very severe brain injury (C). For a load between 20 and 50 Newton, the author was able to turn smoothly at a medium high frequency (**Figure 7A**), but not the 33-year-old patient (**Figure 7D**). He had big problems to manage the difficult coordination's between pace and trot gait and was getting stuck or nearly stuck. He only succeeded to turn rather continuously for the easy coordination's pace and trot gait, used for walking, crawling and running.

Therefore, the author was able to turn smoothly at 1.6Hz and the coordination dynamics value was with 1.9 small (good). The patient was not able to turn smoothly. His frequency of turning was with 0.53Hz low and the coordination dynamics value was with 51.9 very high (bad). Therefore, the author was able to exercise on the special CDT device more than 25 times better. His CNS was functioning 25 times better than that of the patient at these moments.



**Figure 7.** Coordination dynamics measurements, obtained when exercising on a special CDT device (Figure 4). **A, B, D** Healthy and trained person (author), **C** Patient with severe brain injury, 33 years old. Note, the author is able to turn at a high frequency (1.6 Hz) smoothly (low mean arrhythmicity=low coordination dynamics value=1.9) A), but the patient can only turn at a frequency of 0.53 Hz very unregularly (very high arrhythmicity=very high coordination dynamics value=51.9).

The patient was not able to exercise at higher loads (Newtons) because his CNS functioning was not allowing it and because of breathing problems due to a damage of the breathing center in the reticular formation. He was not getting sufficient oxygen for harder work.

When the Author was turning at high load (140 N; Figure 7B), his frequency of exercising was getting lower (1.12Hz) to escape the load and his coordination dynamics value was getting worse (larger; 5.7). That means, for higher loads, the coordination between arms and legs is not as good any more, also for the healthy case.

The author was training approximately 15 h per week to get younger. Mostly, he was training fast walking and jogging too little, what is actually not so good. When during one week he performed fast walking for two hours every day, his walking trot gait pattern got transiently overloaded for a high load of 161 N. This can be seen on the coordination dynamics trace (Figure 7D). For this very high load, his CNS had problems to generate the easy pace and trot gait patterns. On the coordination dynamics trace, it is therefore possible to see for which patterns during pattern change the training person has problems.

Coordination dynamics measurements are therefore able to show with what patterns the training person has

problems and with the coordination dynamics value one gets a single value for the quality of CNS functioning and can measure changes of CNS functioning during treatment. This single value for the quality of CNS functioning for low and high load will be used to measure health improvements transiently in the short-term memory and over the years in the long-term memory.

**RESULTS**

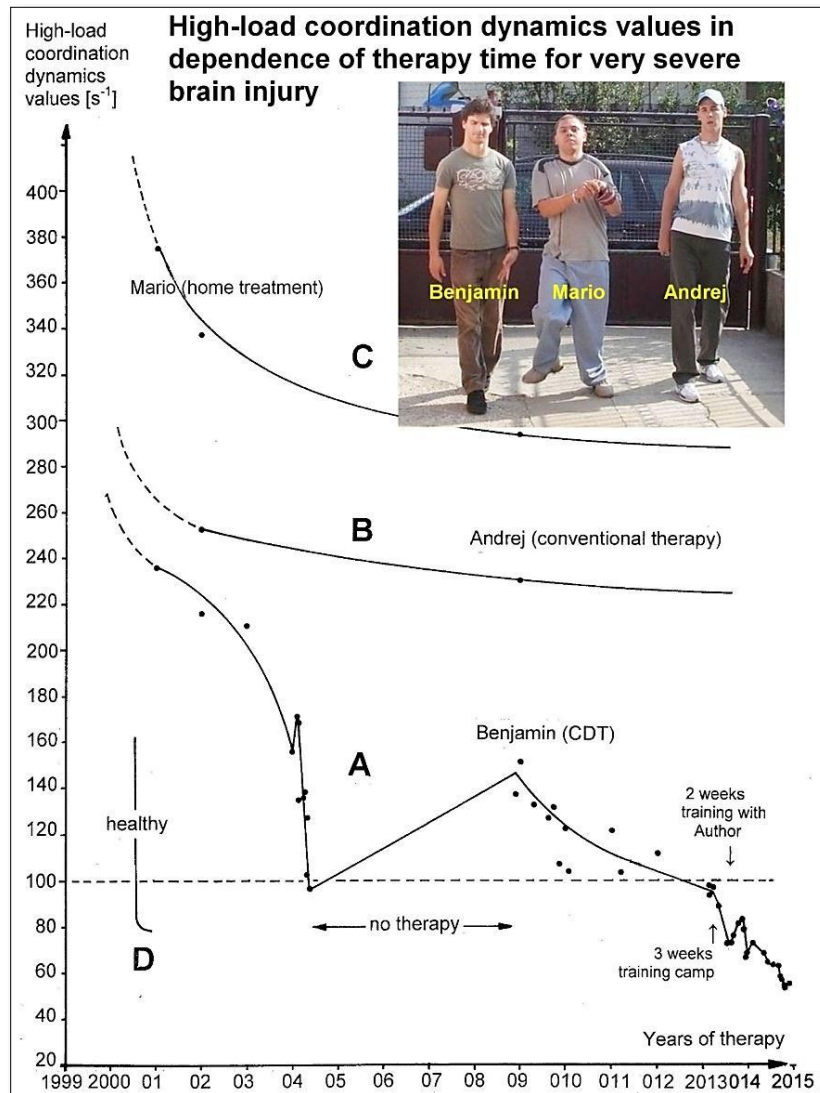
**Movement-based learning has to start in the vigilant coma, has to be efficient and long-lasting**

The three boys, aged nine, twelve and fourteen years old (Benjamin, Mario and Andrej, respectively), suffered severe brain injuries almost at the same time, two in a car accident and one in a bicycle accident. In the nine- and fourteen-year-old patients, intensive coordination dynamics therapy (CDT) was started approximately five to ten weeks after the trauma in vigilant coma stage. The two patients recovered unexpectedly early from the coma and progressed quickly in their recovery of motor functions. They re-learned running after four months of therapy, even though their loco motor functions were still far from normal. The twelve-year-old Mario did not obtain intensive CDT, only conservative physiotherapy because of many infections and complicated bone fractures, which were not invasively reconstructed. The patient recovered much later from the coma (six months

as opposed to six weeks) and had severe extensor spasticity, shortened tendons, problems with several joints, pain, reduced mental functions, grasp reflex in the right hand (reappearance of infant automatism) and nearly no useful motor functions in his legs. Mario received intensive CDT following a delay of five months.

The outcome of movement-based learning of the three patients is compared in **Figure 8**. Benjamin could substantially improve CNS functioning, quantified by the reduction of the coordination dynamics (CD) high-load value. Mario and Andrej could not reach low CD values.

Their CNS functioning could not be improved much. Healthy children can improve CNS functioning much faster (**Figure 8D**). With respect to the rate of learning, the rate of forgetting and reaching a meaningful life, it will be concentrated on the patient Benjamin because CDT was administered to him over 20 years and changes of neural network learning assessed. For details of the three cases see [15,19,20]. In short, only Benjamin obtained a rather optimal CDT and reached a meaningful life. He successfully finished his university study and won the bronze medal in 100 m sprint (14 s) in 2016. Mario and Andrej are living at parents' home as disabled adults.



**Figure 8.** High-load coordination dynamics (CD) values in dependence of therapy in the three patients with severe brain injury. **A)** Benjamin (CDT), **B)** Mario (home training) and **D)** Andrej (conventional therapy), 9, 12 and 14 years old when the therapy was started. The improvement of high-load CD values of healthy pupils upon repeated exercising on the special CDT device are inserted according to scale (D). Note that the high-load CD values of Mario and Andrej are far away from the healthy case with respect to values and time for improvement. The high-load CD values of Benjamin reached the values of healthy pupils but with much more time of exercising. Note the high values of the high-load test at the beginning of therapy. No CDT measurements were available at the very beginning.



**Figure 9** shows the improvement of running of Benjamin over the years of CDT. His running pattern is very good for a patient with very severe brain injury, whereas his

walking pattern is poor. He is training now with healthy athletes.



**Figure 9.** Relearning of running in the patient Benjamin with severe brain injury. **A)** Coordination dynamics therapy was started in the final vigilant coma stage. The author is supporting the legs. The patient was very afraid when treadmill walking was administered to him. **B, C)** Running 8 months and 15 years after the car accident. Note, the running after 15 years is faster and better, but the spasticity of the left hand seems to be worse (**C**) than 8 months after the accident (**B**).

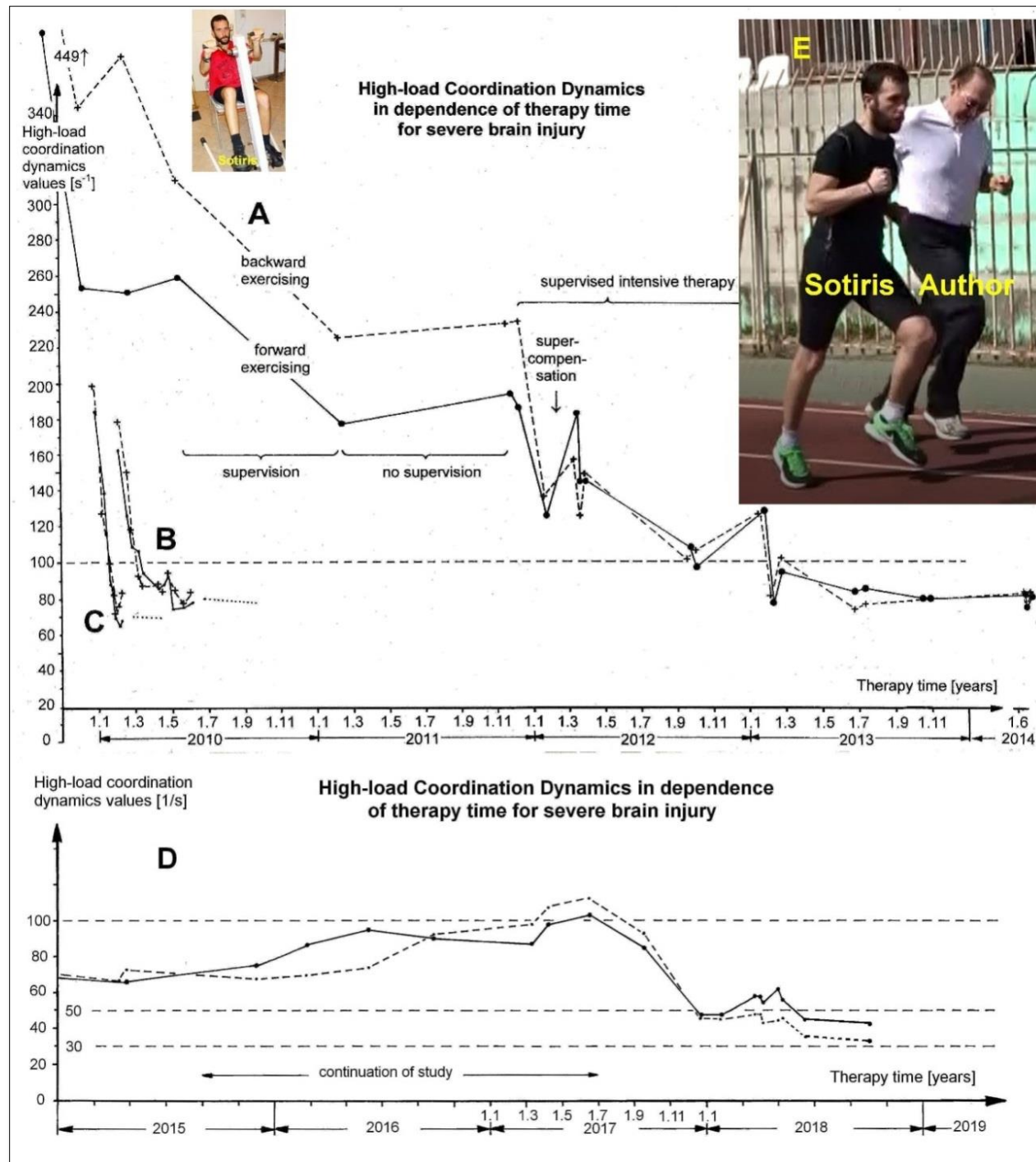
#### Old-learned movements for repair in severe brain injury and aging

The patient Sotiris (**Figure 10**) suffered a severe brain injury at an age of 22 in a car accident. He was also given up by school medicine. His brain injury was rather balanced, so that he could perform many movements a bit. Through 10 years of CDT he improved substantially. His improvement of CNS functioning by learning can nicely be seen in **Figure 10A-D** by the high-load CD values. The values improved (got smaller) very much during the 10 years (**Figure 19A**) till they reached nearly a plateau. However, when finishing his university study and exercising only 7 h per week, he got worse again as judged by the CD values (**Figure 10D**). Through increasing the intensity of CDT again and upgrading the therapy, further progress was still possible (**Figure 10D**). The upgrading included further movements and old-learned movements. Here it is concentrated on the old-learned movements in similarity to the old-learned pattern

playing violin of the former permanent coma patient Manolis [16].

Before the accident the patient Sotiris had learned to drive a car. After the accident, he could re-learn to drive a car, because the old-learned movement car-driving was still in his movement-memory. As an engineer student before the accident, he re-learned also a bit the movement patterns to file (**Figure 11B**), to drill, to lathe and other pattern skills which a mechanist or engineer has to be able to perform.

The question was now, is he still able to perform these skills and can they be used for further brain repair. With the help of the university and his sister he managed to successfully finish 10 years after the accident the university study as an engineer. But to work as an engineer, he has to be able to perform the necessary skills apart from using computer-driven machines. A test was undertaken to proof how good he can still perform these skills and were they really old-learnt patterns.



**Figure 10.** A) Improvement of high-load coordination dynamics (CD) values of the patient Sotiris with severe brain injury through CDT for approximately 10 years. The high-load CD values were obtained by summing up the single CD values for forward and backward exercising,  $\Delta$  (high-load CD value) =  $\Delta 20N + \Delta 50N + 100N + \Delta 150N + 200N + \Delta 150N + \Delta 100N + \Delta 100N + \Delta 50N + \Delta 20N + \Delta 20N$ ). B, C) For comparing the rate of repair, the improvement curves of the high-load coordination dynamics values of an athlete (C) and a healthy pupil (B) are inserted. Note that the brain-injured patient needed much more time to achieve similar good CD values. D) Continuation of therapy. The substantial improvement of the high-load CD values (lower values) in the middle of 2018-motivated Sotiris to continue his therapy at the limit. E) Sotiris running in interpersonal with the author in the trot gait pattern.



**Figure 11. A)** The author during filing. He is able to file a plane. **B)** Sotiris is not able to file a plane. As the teacher/father said, also his posture during filing is wrong.

**Figure 11** shows the author (**A**) and the patient Sotiris (**B**) during filing. The author learned the filing 60 years ago when he was becoming an electro-mechanist at the firm Siemens-Halske in Berlin and was still able to file a plane surface as measured with a lineal! The patient Sotiris was not able. He could file, but not in a real quality way. Obviously, Sotiris did not really learn in his engineering study the quality filing and this filing did not become an old-learned movement. Therefore, this remnant filing pattern cannot be used for brain repair and also not for being a good engineer.

The next step was now, how was it with the other skills for being a mechanist or engineer. As found out, Sotiris was not able to saw metal properly (**Figure 12A**). With the turning lathe, he was able to lathe (**Figure 12B**) and drill holes (**Figure 12C**). He was able to caliper with a slide gauge, having a vernier scale for measuring the 1/10 of a mm (**Figure 12D**). To measure and to lathe was stored in his memory, but not to fix a rod in the lathe chuck.

The author could perform the learned filing of a plane surface after 60 years, the patient was not able to do it after 10 years. Since Sotiris could perform the old-learned movement ‘car driving’ and could not file a plane surface, it seems that Sotiris never really learned the proper filing as the author. This means that only really learned patterns during development or later are special qualities of brain functioning, which can be used later on for brain repair if necessary. The learning of movements and skills is important for the development of a good functioning brain. Pushing buttons and working with an iPhone are no substitutes for old-learned movement patterns. The brain development of such persons is poorer and has less quality for repair. The same holds for continuous writing and digital writing at school. Continuous writing is a high-quality connection between intelligence and movement and its learning should not be given up at school. In brain injury and aging, such learned quality movements can be used for brain repair.



**Figure 12.** The patient Sotiris, 10 years after a severe brain injury, during sawing **A)** lathe **B)**, drilling **C)** and **D)** calliper.

The 71-year-old patient of **Figure 13** with a hematoma on the right side and anaplastic oligodendroglioma WHO grade III on the left side (**Figure 13**, inset) has big problems with the speech and movements like crawling and jumping, but can elegantly cycle (**Figure 13**) three months after the removal of the tumor and radiation

therapy. Before the operations he was a very good cyclist and after the therapies he can nicely cycle and manage with the traffic, which is unbelievable.

In conclusion, only deeply learned patterns are helpful for brain repair in brain-injury and aging.



**Figure 13.** A 71-year-old patient during cycling 4 months after removal of an anaplastic oligodendroglioma WHO grad III (inset; cancer size approximately 60 mm x 32 mm; poor prognosis). Hematoma removal 2 years earlier. New MRI after the operation not available so far because of radiation therapy. In the background a montage to show that the patient can easily turn around with the bicycle. Cancer and speech (speech centers are damaged on both sides) are the main problems following 4 weeks of CDT. Hopefully CDT can inhibit cancer growth [17] substantially so that the patient can live longer with better quality of life.

### Competition between power and coordination or between brain repair in injury and aging

An old problem in aging is, how much can an aging person compete with the younger ones, especially when it may be possible to live longer with a better quality of life by 20 years through healthy living (optimal nutrition, no stress, physical exercise) and performing CDT. Can experience and knowledge be beneficial for the aging person?

To get the fully understanding of the following high-load test comparison with respect to load, a few explanations/comparisons are given in beforehand. A high-load CD value of 50 is a good value and the person is probably fit. A value of 30 is a dream high-load value, which is difficult to achieve. The person is probably top fit and has a good functioning CNS. Top athletes will probably have a high-load CD value of 50 when measured the first time. With repeated exercising on the special CDT device, they will improve the coordinated arm and leg movements to reach a value of 30 and can improve their sport performance. Coaches in football or tennis understand that for success not only power is needed besides a good technique, also coordination is needed. But they do not understand that the coordination can efficiently be improved, when exercising on the special CDT device.

The top athlete Andrus Värnik won with 87.17m a gold medal at the 2005 World Championship in javelin throw. In 2002 (25 years old) his high-load CD value was 56.6, when exercising the first time on the special CDT device. His best low-load CD value was 4. If he would have performed the low-load and the high-load tests two or three times more, his high-load values would have improved by 30 to 35% (**Figure 5** of [27]). He probably would have reached a value of approximately 40 (**Figure 14**, indicated by an arrow). Normally, athletes have better high-load CD values (for power generation) and musicians better low-load values (for fine control) [26, 27]. When Andrus Värnik reached during the high-load test the 150 and 200N, he turned faster. He was therefore a real athlete with plenty of power. When the author comes to the 150 and 200 N, he turns slower to escape from the load; he lacks power which is typical in aging.

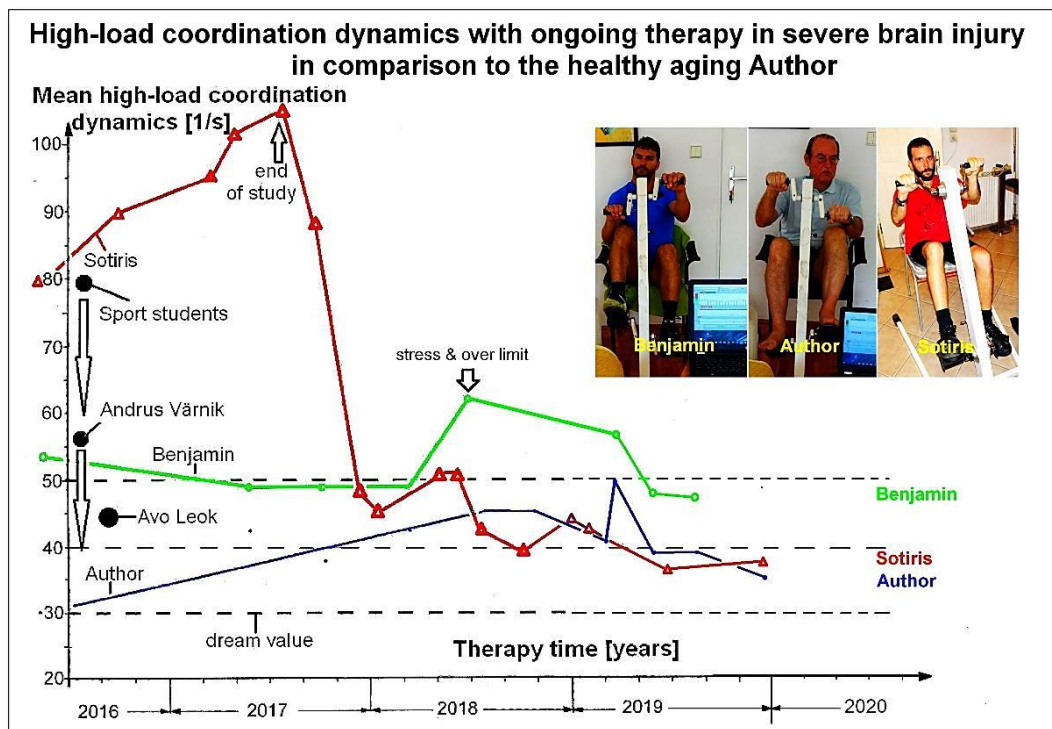
Fit young men at an age of between 15 and 18 years could reach with repeated exercising a high-load value of between 60 to 50. Sport students have on average a high-load CD value of 80 when exercising the first time. With repeated exercising they would reach a value of 60 or lower (**Figure 14**).

Women can exercise on the special CDT devices as good as men for low and high load, even though they have less muscle power due to a lower percentage of FF-type muscle fibers. But because they have a higher percentage

of FR and S-type muscle fibers (**Figure 30**), they can keep the high load longer, which is also needed during the high-load test. With respect to the coordination dynamics, the women's brain works as good as that of men, even though their brains are smaller.

The motor cross athlete Avo Leok suffered a complete thoracic spinal cord injury during a motor cross competition. A sponsor (!) informed Avo about CDT and supported him financially with the treatment (Google – Avo Leok recovery story). Avo could reach a high-load CD value of 44.2 (**Figure 14**) in 2007 (36 years old). But his value is only partly comparable to the other values because he was a paraplegic and exercised therefore mainly with the arms, so that the complicated coordination's between arm and leg movements were only little activated. Still, he was a great sportsman because he was fighting for a better future even when having suffered a spinal cord injury (SCI). Unexpectedly, many other famous athletes, who have suffered a SCI, did not fight by movement-based learning to partly repair their SCI suffered during sport events. Avo was fighting for a repair of his SCI through CDT. But against the advice of the author, Avo had a stem cell therapy administered to him in Moscow. He wanted the miracle. When the stem cell therapy did not work, he lost the motivation to fight for a further repair of the SCI even though the sponsor would have supported him financially.

The author reached in 2016 with approximately 15 h CDT per week the dream value of 30 (**Figure 14**). After that, the CD value went into the direction of 50 in 2018, which means, he could by far not hold the dream value. An explanation would be that he got older (depressive for the author) and lost power which is also needed for a good high-load CD value besides a very good coordination between arm and leg movements. Other reasons like illnesses (infections) may also have ruined the dream high-load CD value of 30. With intensified CDT and including exercising at 200 N, the author could reach a value of 35 again. Still this good health value is away from the dream value of 30. But the benefit from this hard work was that a small wound in the face, which did not heal for two years, healed. It seemed that also the eye function improved a bit, which became impaired following chemo and radiation therapy during cancer treatment 11 years ago. Even though it was very hard to exercise at 200 N, the author got the benefit of health improvement. With respect to health improvement it is interesting and very important that during exercising on the special CDT device, especially at higher loads, the body finds the places in the body where something has to be repaired. Often these places are itching during exercise.



**Figure 14.** Mean high-load coordination dynamics (CD) values in dependence of ongoing coordination dynamics therapy (CDT) (for definition see **Figure 10**) of the now 31-year-old brain injured Benjamin and the 33-year-old brain injured Sotiris and the 78-year-old author after cancer treatment 10 years ago. High-load CD values between 30 and 50 are very good values which athletes may reach. The high-load values of Andrus Värnik and Avo Leok are included, measured in 2002 and 2007 respectively; the arrow indicates for Värnik the probable improvement with further CDT. The values of sport students and the values they can reach (arrow), with a few times exercising, are between 60 and 80. The approximate values of physiotherapist (130), gymnasts (150) and musicians (150) for exercising the first time are not fitting into the figure. Note that the values of Benjamin, Sotiris and the author are in the range what top athletes may reach when they exercise at least a few times on the special CDT device. The very good CD value of 30 (dream value) only the author reached so far. The feet of the patients had to be fixed for the test, the ones of the author not.

The patient Benjamin could reach after 17 years of CDT in 2017 the value of 50 when exercising 30 h per week. But when he had a lot of stress and may be went over the limit of exercising, his physical performance got worse. His high-load value was over 60 in 2018 (**Figure 14**). His coach, training him to run faster (faster than 14 s per 100 m) and jump longer distances, did not understand the functioning of the special CDT device and put some pressure on him not to use the special CDT device. When Benjamin could reduce the stress and did not overload himself any more, his high-load CD values went under 50 again.

The patient Sotiris could improve his CD values over the years with 30 h CDT per week (**Figure 10A**). But when he studied and could train only 7 to 10 h per week, he got worse again and had a high-load CD value of over 100 (**Figure 10D**). When he finished successfully his university study, got rid of the study stress and could exercise again 30 h per week, he got much better. His CD values went continuously under 50 with some disturbance

when upgrading the therapy. He even became able to beat the author at the end of 2018 (**Figure 14**). When Sotiris reached the value of 40, he became able to speak more clearly. Therefore, not only his CD values got better with the intensive therapy but also the clinical performance improved (the speech).

The comparison between Benjamin and Sotiris is interesting with respect to the applied CDT. Sotiris trained optimally to repair his nervous system and reached very good high-load CD values. Benjamin, on the other hand, trained with respect to two goals. Firstly, to repair further his nervous system and secondly, to run faster and try to win Olympic games or other competitions for disabled. Sotiris could put all his power to the repair of his nervous system and Benjamin had to split his power into CNS repair and running improvement. Sotiris was more successful in repairing his CNS and achieved the better (lower) values. For improving the health, therefore, it is also important what kind of physical activity the patient is performing. Exercising on the special CDT

device and jumping, for example, are more successful to improve the urinary bladder continence than running or walking fast.

In conclusion, the 30-year-old Benjamin and the 33-year-old Sotiris with severe brain injuries could still improve their health, following brain injury, when training close to limits with approximately 20 to 30 h per week. Their reached high-load values are in the range between 30 and 50 (Figure 14) what only athletes can reach. Optimal CDT has therefore similarity to the training of athletes. The athletes fight for top values, let's say to run 100 m in 10 s, and the patients fight for getting back the normal everyday health, even though a complete cure is not

possible so far. These young patients have plenty of power and are fit, but they need to improve the phase and frequency coordination among neuron firing to improve the physiologic patterns and to train hard so that other parts of the CNS can take lost or impaired functions over by plasticity. The 78 years old author could keep a quite good health through 10 years of CDT with 10 to 15 h therapy per week and compete with the young fit patients. The lack of power he compensated by a better coordination. When the patient Sotiris got better than the author in 2018 and 2019 (Figure 14), he got shocked. The question for the author was, can he improve his power during exercising to compete further with Sotiris and keep the top fitness and health?

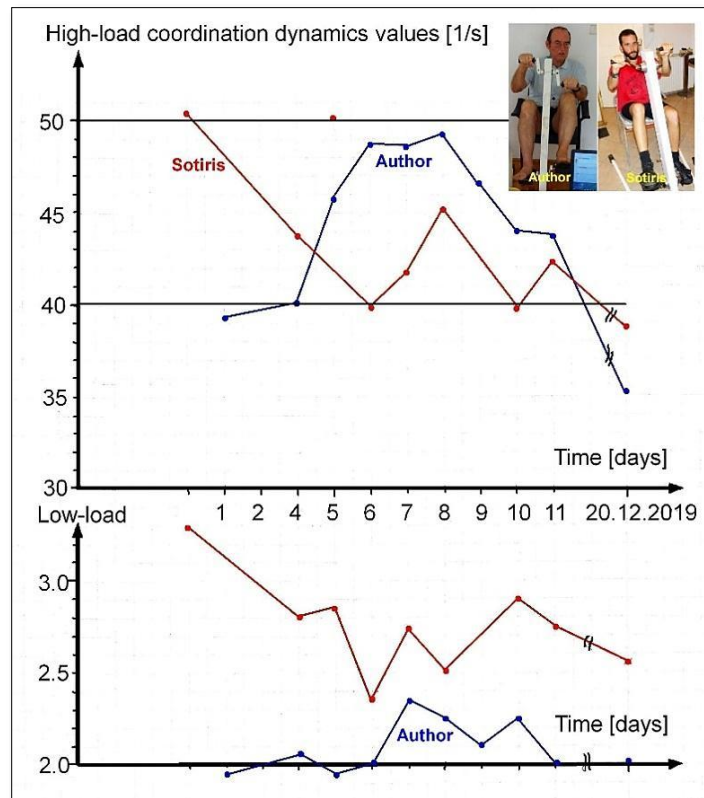


Figure 15. Increase and decrease of high-load coordination dynamics values of the rather healthy author in relation to the brain-injured patient Sotiris. The patient did not exercise every day and the improvement of treatment is not so clear. The author could turn much better for low load.

The author took all his mental discipline to perform the high-load test every day, that means going every day to the limit. Figure 15 shows the changes of his high-load CD values when exercising at high loads every day for more than 10 days. With repeated exercising the CD values got higher (worse), because the author's CNS/body became exhausted. But after reaching the value of 49 the values reduced again and following a short period of relaxation, a value of 35 was reached. He could reduce his high-load values from 39 (at the beginning) to 35 and could beat Sotiris again, even though also Sotiris was

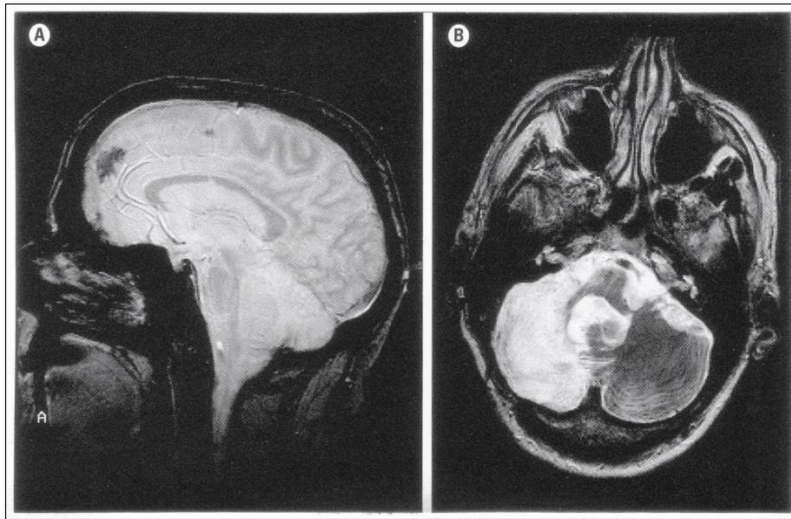
exercising at high loads simultaneously. This means that also in aging the power can still be increased if exercising at limits. The period of training was 20 days. The author could clearly feel that the power was first reducing with every day training before increasing again. But such a high load power training is a 'horror trip'.

When a physician is performing the same treatment as the patient, if possible, he learns about all the problems with the treatment. Maybe high-load training can also be used to inhibit more strongly cancer grows in suitable patients (see below).

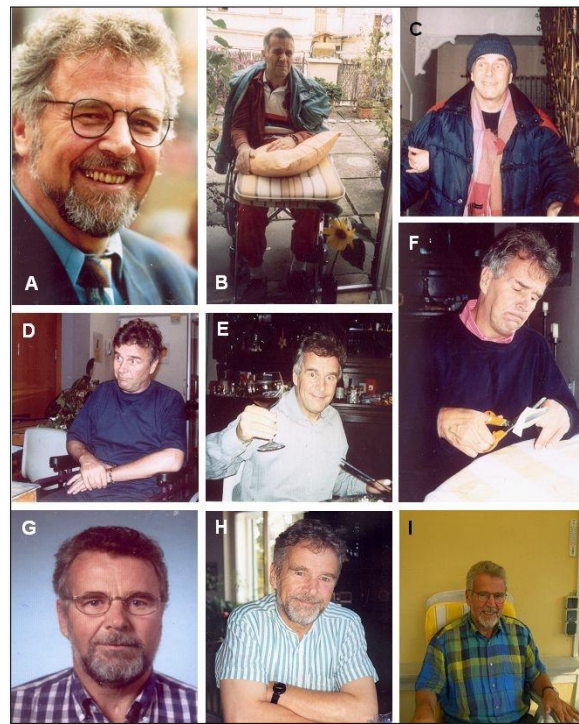
**To live longer with a better quality of life in a patient with severe cerebrum and cerebellum injury**

The 55 year old Dr. Cwienk suffered a very severe traumatic cerebellum injury and a severe brain injury (Figure 16). He lost approximately 80% of his cerebellum. After the operation he could move only one

finger when giving his wife the hand. The wife was strongly fighting with the physicians not to give him up and was looking herself for treatment of the husband. A few years later CDT was started. Out of a seemingly hopeless situation and prognosis, he improved strongly with therapy over the years. He was a very cooperative patient. It has reported earlier about him [19].



**Figure 16.** Magnetic resonance imaging (MRI). A 55-year-old patient who suffered a severe cerebellar and cerebral injury. The cerebellum has been destroyed to approximately 80% (B, light parts of the cerebellum). There is a loss of brain tissue in the frontal lobe (A, dark areas of the forebrain).



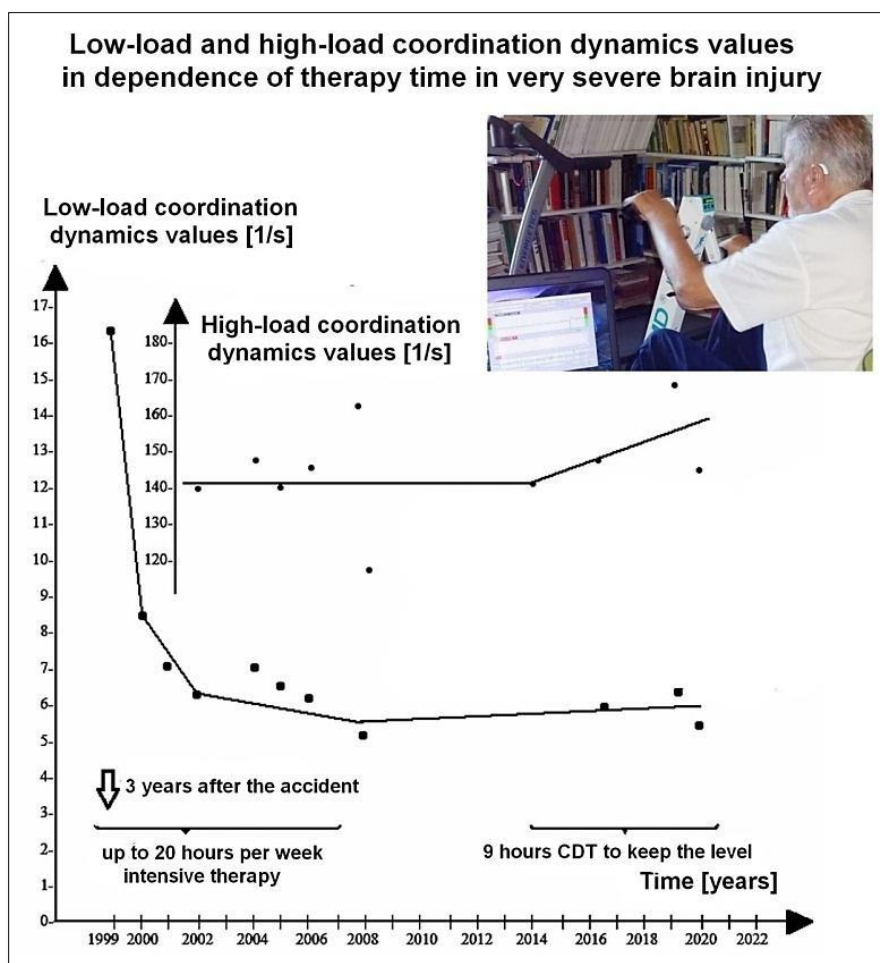
**Figure 17.** Therapy-related improvement of the face impression of a patient who suffered severe cerebellar and cerebrum injuries. A. before the accident; B-I after the accident in 1995 till 2006.



**Figure 17** shows the improvement of CNS functioning in his face. **Figure 17A** shows the intelligent patient Dr. Cwienk before his severe brain injury. His face shows not only a friendly expression, but also some power of intelligence. After suffering the severe brain injury and partly recovering from it during 10 years of CDT, he shows in **Figure 17I** a friendly face again, but the power of intelligence is missing. He himself used to say: “Before the injury I could do two things at the same time, but now

only one”. The mental and emotional states of a patient can partly be seen in the patient’s face expression.

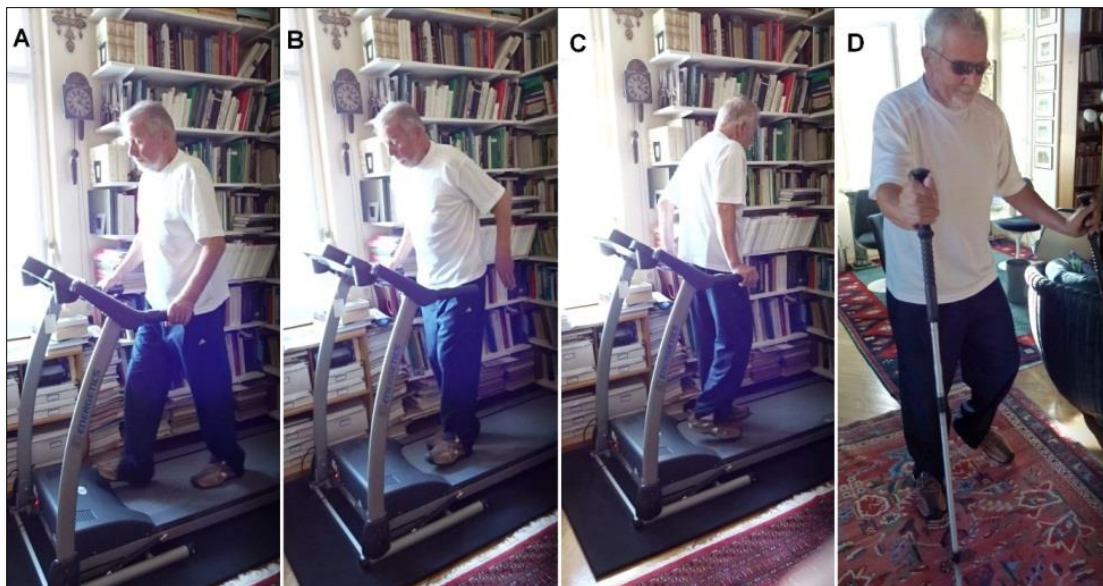
**Figure 18** shows the improvement of patient Dr. Cwienk via the low-load and high-load CD values. The low-load values improved (got smaller) strongly with intensive therapy. Later, with CNS improvement, high-load measurements became possible. When in 2014 he reduced the intensity from 20 h per week to 9 h, he could not fully hold the level. His CD values got a bit worse.



**Figure 18.** Low-load and high-load CD values of the patient Dr. Cwienk with a cerebrum and cerebellum injury. Note, 9 hours CDT per week are not sufficient for him to keep the level.

The now 80 years old patient was performing CDT nearly every day for 20 years to keep the level of health. Colon cancer treatment was successful. When he stopped therapy for three days or more, he was going backwards physically and mentally as his wife said and also, he himself. When he wants to go on with his meaningful life, he has to train every day. The patient is exercising on the special CDT device (**Figure 18**, inset) and walking on treadmill (**Figure 19**). Because of severe balance problems, he needs at least the support with one hand when walking on treadmill (**Figure 19B**).

Scientifically very interesting, his protection automatism were coming back after 20 years of CDT. It is believed that the protection automatism are sited in the cerebellum. Indeed, after losing most of the cerebellum, he could not protect himself when falling. He moved completely unphysiologically. This was a big danger when walking with him. But with the repair after 20 years through CDT, the risk of damage is not so big any more while falling.



**Figure 19.** Walking on treadmill of the now 80-years-old patient with severe cerebrum and cerebellum injury. **A)** At a speed of 2km/h the patient walks smoothly over the heel. **B)** When walking with one hand holding, he trains balance. **C)** During backward walking, he walks over the forefoot with flexed knees. **D)** During walking with sticks, it can be seen that he learned to flex a bit the knees.

Through CDT, the patient Dr. Cwienk became able to live longer with a better quality of life, but he has to fight every day for a longer life. He is still able to have a

meaningful discussion with the author and giving him coffee with some coordination problems (**Figure 20**).

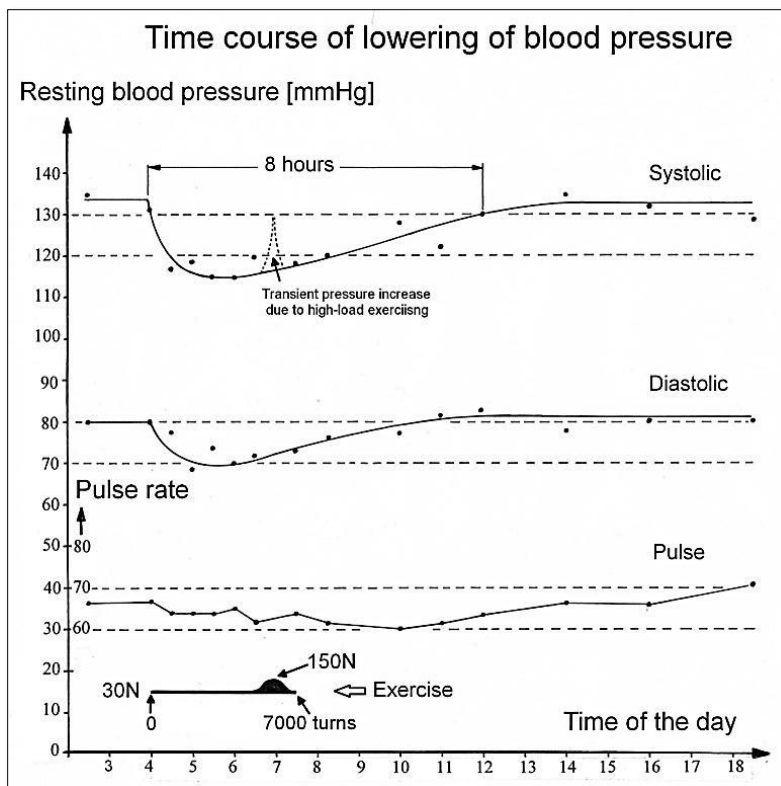


**Figure 20.** The intelligent patient Dr. Cwienk following 20 years of CDT at an age of 80. He gives the author (right) coffee. A high-level discussion is still possible with him, because the patient did not lose his memory with the severe brain injury.

**Time course of blood pressure lowering achieved when exercising on a special CDT device**

When exercising on a special CDT device not only the CNS can be repaired, but also the blood pressure can be

lowered. **Figure 21** shows the time course of the resting blood pressure lowering when exercising at low and transiently high load on the special CDT device.



**Figure 21.** Time course of the lowering of the arterial blood pressure when exercising at 30 N (and transiently up to 150 N). Note, measured transient pressure increase due to high-load exercising (dashed line) is indicated. The blood pressure lowering was measured in the author.

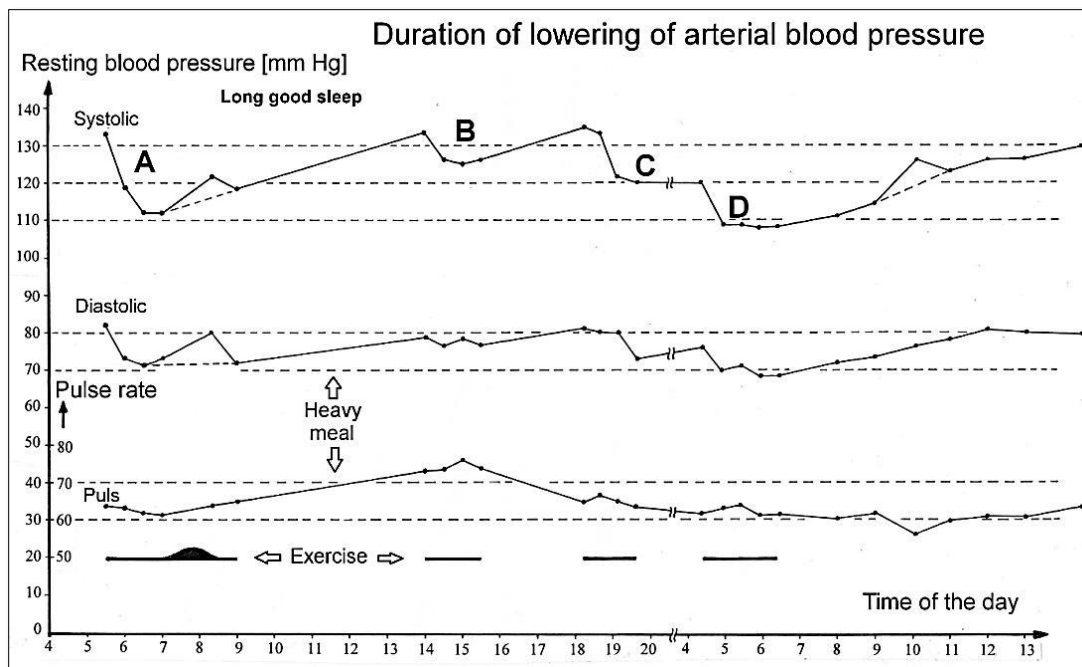
As can be seen from **Figure 21**, a rather healthy fit person over 70 probably has a transient resting blood pressure lowering for approximately 8 h. This healthy lowering of the blood pressure could be used for patients with hypertension. When exercising every 6 h for 60 min (2000 to 3000 turns), including transiently against higher loads, he can probably lower his resting systolic blood pressure by 10 to 20 mmHg. If he has no adverse heart problems, he does not need to exercise at night, but if he has, maybe he should also train once at night. Most elderly get up at night. It would therefore be no problem for them to exercise also at night. An exercise session before going to sleep most likely increases the length and deepness of the sleep.

One could argue that this repeated exercising is a big effort to just reduce the systolic blood pressure by 10 to 20 mmHg. Such lowering of the systolic blood pressure could be easily achieved by medication. But one should not forget that simultaneously the functions of urinary bladder (continence [7]) and kidneys are improved, the sexual function is improved, the cardiovascular performance is trained, cancer growth is inhibited (including breast and prostate cancer [17]) and the nervous system (including the vegetative nervous system) is repaired or in its functioning improved. The lowering of

the blood pressure by exercise would be only one part of the improvement of health. Probably many regulations will improve simultaneously. The time course of the lowering of the blood pressure is probably an indicator for the time course of improvement of other body functions.

#### Repeated lowering of the blood pressure to reduce the pressure during 24 h

To lower the blood pressure rather continuously, the exercising on the special CDT device has to be performed repeatedly. Such repeated lowering is shown in **Figure 22**. With every exercising the blood pressure went down, but not to the same amount as in **Figure 22A**. After exercising for approximately one hour in the morning after a long good sleep, the systolic pressure reduced by 21 mmHg (A). After stopping the exercise, the pressure slowly increased. When exercising again, the pressure lowered again, but not so much, only by 9 mmHg (B). Exercising for a longer time would not have helped, because the lowering had reached its maximum under that condition. Also, further exercising would have not reduced the pressure further. The special condition was, that the author had a heavy meal before and probably blood was needed for digestion, which increased the blood pressure.



**Figure 22.** Repeated lowering of the resting blood pressure (A, B, C, D) achieved by exercising on a special CDT device during two days following long good sleep. The pressures were measured before exercising and then mostly every 1000 turns; once up to 7000. Each pressure was at least the mean of three values. Exercise durations are indicated by bars.

Following another exercise in the early evening, the systolic blood pressure could be lowered again by 15 mmHg (from 135 to 120 mmHg; **Figure 22C**). From feeling it seemed that the heavy meal was mainly digested at that time. Next morning at 4.30 after a good sleep, the systolic blood pressure was still low and could be lowered from 120 mmHg to 109 mmHg. With no eating the blood pressure lowering lasted for 7.5 h (**Figure 22D**).

In conclusion, the systolic blood pressure could be lowered successively by exercising several times for one or two hours. The lowering lasted up to 8 h depending on the situation.

Coordination dynamics therapy (CDT) can partly repair the brain, can inhibit to a certain extent cancer growth and can reduce the blood pressure. There are patients who have all three problems and through CDT all the three diseases can be treated simultaneously without negative side effects. The treatment of such a patient will be shown below.

#### Movement-based repair in a brain-cancer patient

The 71-year-old patient Hans (**Figure 4 and 13**) was introduced to the author for a brain repair through CDT. The patient had an older undetected hematoma, not caused by an accident (aneurism or other tumor?), which injured his brain. Acutely the patient came for brain repair

after a brain cancer treatment. Because of the removed anaplastic oligodendroglioma WHO malignancy grade III and the old removed and not really treated hematoma, the patient had the symptoms of a severe brain injury on both hemispheres (**Figure 13**, inset). Because of the high malignancy, growth of remaining tumor cells has to be expected and inhibited. The side effects of the applied radiotherapy will be perceived most likely only later on. In the author the side effects of chemo and radiation therapy appeared after one year and lasted for more than 10 years. Additionally, the patient had hypertension. His medication was Lisinopril.

Through administering CDT to the patient for 9 weeks with 20 h therapy per week, the brain could partly be repaired, the cancer growth hopefully to a certain extent inhibited and the hypertension reduced in the short-term memory. The main life-treating problem was the cancer. To what extent the cancer growth can be inhibited so that the patient can live longer with a better quality of life will the future show.

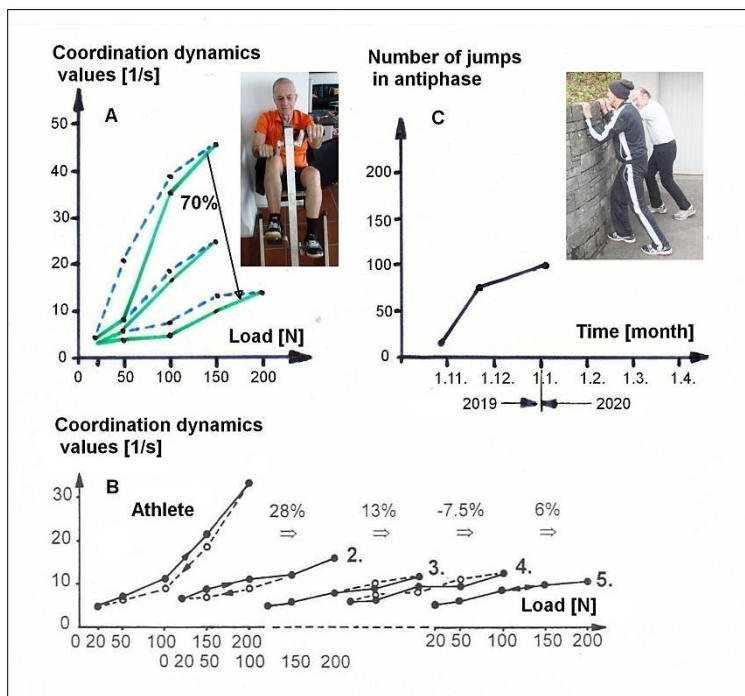
**Figure 23** shows the patient during walking at the beginning of therapy (**Figure 23A, B**) and walking (**Figure 23C**) and jogging (**Figure 23D**) after 9 months of therapy. Through 9 weeks of CDT the patient re-learned to walk, run and cycle (**Figure 13**) as a normal fit person.



**Figure 23.** A, B) The patient with a removed oligodendroglioma at the beginning of therapy. The patient was often walking in in-phase (A) and the arm movements were not coordinated with the legs (B). C, D) Nine weeks later, the cancer patient could easily walk in interpersonal coordination with the author (C) and could run even faster than the author (D).

The high-load coordination dynamics values improved by 70% (Figure 24A). The improvement of CNS functioning, quantified by the high-load coordination values by 70% was better than the one in an athlete (Figure 24B), even though the values can only partly be compared, because the athlete trained only with the measurements every two weeks whereas the cancer patient trained 20 h per week. Still this comparison shows the substantial improvement of CNS functioning in the

patient. Impressive was also the blood pressure reduction when taking no Lisinopril. Through the low and high-load test (exercising for one hour) the resting blood pressure reduced from 149/100 to 121/82. Two hours later the blood pressure increased again to 133/87 as expected from the time course of reduced blood pressure (Figures 21 and 22). The patient may not need the antihypertension drug, if he exercises in the morning, the middle of the day and in the evening.



**Figure 24.** A) High-load coordination dynamics (CD) values of the cancer patient for increasing and decreasing load (dashed line). B) Improvement of high-load CD values from a healthy athlete, taken from [27]. The improvements can only partly be compared, because the patient was training much more on the special CDT device than the athlete. C) Improvement of jumping in antiphase, when jumping in interpersonal coordination with the author.

The jumping in anti-phase (**Figure 24C**) also improved but by far not that much as the automatisms walking and running and the old-learned automatism cycling. Since the speech areas were damaged on both sides (**Figure 13**, inset), the patient had big problems with the communication. He could not speak properly, could not find the words, could not really write and had difficulties with reading. The understanding of complicated sentences was not possible at the beginning of therapy. This was to be expected because the speech centers were damaged on both sides. The everyday day life like eating, kitchen work and visiting physicians or hospitals was seemingly normal again after 9 weeks. For the transport he mainly used his bicycle. His quality of life had improved strongly following the operation.

Nothing can be said so far about tumor recurrence. The patient opted additionally for chemo therapy. The first week of chemo therapy impaired the high-load coordination dynamics values, that means the functioning of the CNS, the jumping and probably also other movements, but not the automatisms walking, running and cycling so far. The biggest problem remains, namely, to what extent can the brain-cancer growth stopped or inhibited so that the patient can live longer with a better quality of life. The more cancer patients exercise the more they live longer [38].

## DISCUSSION

### To live longer with a better quality of life through CDT in patients with severe brain injury

It was shown with the three brain-injured boys that only the patient Benjamin, to whom CDT was administered, could reach normal life with some deficits. Probably he can earn his own money in the future through teaching languages. He inherited from the farther to be good in languages and this property was not destroyed by the injury. The young patient Sotiris recovered from the severe brain injury quite well with respect to motor functions. Like Benjamin, he could finish the university study in engineering. He even could perform some mechanical patterns again through 10 years of CDT. Still he cannot carry fully the responsibility for his work. He is not fully back to life. He is not free, because he cannot earn his own money. Benjamin and Sotiris could substantially improve their quality of life through 20 and 10 years of CDT respectively. Probably they will live longer than other brain injured patients who did not obtain optimal therapy for years, because a rather healthy brain can better control the regulatory functions. This assumption is supported by the case report of the intelligent patient Dr. Cwienk. With 55, he suffered a severe cerebellum and cerebrum injury in an accident. With 20 years of CDT, he has still quite a good life when reaching 80. He is financially independent, because he has a good pension after having a high position (Hofrat in

Austria). But the frontal lobe damage impaired his everyday life. Living together with his wife, he has no problems to manage everyday life. It is therefore likely that also people without a severe brain injury will live longer with a better quality of live because their regulations in the body are functioning better. An example for a normal person is the rather healthy author. With respect to science in human brain repair, he is able to compete with the rest of the world with 78 and his motor functions are sufficient to exercise with patients during the movement-based learning therapy. He can even compete with the young men Benjamin and Sotiris with respect to the high-load coordination dynamics measurements. The more power of the young patients Benjamin and Sotiris, he compensates by a better coordination.

### Brain cancer treatment through CDT

The most important property of CDT is that it repairs several functions simultaneously and especially in severe diseases like cancer. In brain cancer with high malignancy, the brain can be repaired, further cancer growth inhibited and even hypertension reduced simultaneously through CDT. This cancer growth inhibition is very important in brain cancer with high malignancy, because the cancer cannot be removed rigorously, since otherwise the patient has no quality of life any more after the operation. Especially in brain cancer patients under 10 years a more complete cancer removal is possible because more repair/plasticity is possible through CDT. An important feature of the movement-based learning therapy CDT is that it can be used simultaneously with any other cancer treatment.

Astrocytoma and oligodendroglioma are aggressive tumors with high malignancy. They grow through infiltration and it is impossible to remove too much brain tissue. In a 27 years old lady an astrocytoma was removed and CDT administered. First the lady got better and then she got worse again when the cancer grew bigger and bigger and later on, she died. The author did not directly administered CDT to that lady. But the 71 years old patient with an anaplastic oligodendroglioma WHO grade III is treated by the author, and he will use all the tricks to make him live longer with a better quality of life. The quality of life of that patient could be improved strongly and quickly at the beginning of CDT, but the frightened question is to what extent can the cancer growth inhibited.

The author himself suffered a 'squamous cell carcinoma (epithelioma)' (a malign tumor) in the maxilla. After the cancer removal from the maxilla, he was advised to do radiation and chemo therapy to reduce the probability of cancer recurrence. Because of the severe side effects of radiation and chemo therapy, he complained to the surgeon 10 years later for advising him to administer also radiation and chemo therapy. The surgeon replied that he

had only statistical data available for suggestions and not case reports. Therefore, case reports are also needed to suggest proper treatment to the patient. The side effects of chemo and radiation therapy are underestimated because often the patients do not live sufficient long to experience them.

### **The drawing back in organ donation from brain-dead humans**

The demand for organs significantly surpasses the number of donors everywhere in the world. There are more potential recipients on organ donation waiting lists than organ donors. There is therefore strong interest to get more organ donors. Since further with a long-lasting movement-based learning therapy no money can be earned, but money can be earned with organ transplantation, there exists the possibility that little efforts are taken to keep patients alive in cases of very severe brain injuries.

There are two main methods for determining voluntary consent of organ donation: “opt in” (only those who have given explicit consent are donors) and “opt out” (anyone who has not refused consent to donate is a donor). In Germany, which uses an opt-in system, has an organ donation consent rate of 12% among its population, while Austria, a country with a very similar culture and economic development, but which uses an opt-out system, has a consent rate of 99.98%. There are many EU countries who have an “opt out” system. In Germany and Switzerland, it is intended to change from the “opt in” to the “opt out” system of organ donation. The parliaments will probably decide what donor system will be applied. The problem is, that the parliaments may decide without medical knowledge. A law may come which legally kills patients, as will be shown now.

When in Switzerland a law was established about research on brain-dead humans, also the author was asked to contribute with his knowledge, because he was the only one, who worked on brain-dead humans in Switzerland. The author worked on healthy humans, on humans with mild and severe brain injuries, on coma patients, on brain-dead humans and on cadavers. But he was not asked in Germany or Switzerland to contribute with his knowledge with respect to organ donation. With organ donation there is an ethical and medical problem. Here it will be concentrated on the medical problem. Persons who are strongly on the side on an “opt out” system should go and have a look how it looks like when organs are removed from a brain-dead human. In a brain-dead human the heart is still beating and the body is respirated. The way deceased persons are handled, will have repercussion on the way of life of the living human. To be altruistic is good, but one has to know also the medical facts.

It was published that the permanent coma patient Manolis recovered from coma through 4 to 5 years of CDT and re-learned to speak after 6 years of CDT [16]. A potential organ donor even recovered spontaneously from coma after 7 months and CNS functioning improved strongly through three therapy sessions [29]. The problem is that the universities with respect to brain repair are 30 years out-of-date and there is no intention to upgrade their teaching system. Young physicians do not learn at the universities that much more repair is possible in even very severe brain injury. Neurologists, rehabilitation physicians and physiotherapists are reluctant against progress through movement-based learning in brain repair.

The problem in very severe brain injury is that without therapy, often the brain is drifting in the direction of brain death through build up toxins and wastes in the body. There are three possibilities on how the patient dies; he is staying in the coma permanently; he dies on a complication in the coma or he is used as an organ donor after letting him drift into brain death. The operating neurosurgeon, who operated several times the patient Manolis who recovered from coma, predicted according to his experience with rehabilitation, that Manolis will not come out-of-coma and will live at best for another 5 years. But CDT made him move and speak again through 6.5 years of CDT with 20 h therapy per week. A further problem is that physicians and hospitals have big problems to admit that they have done a mistake so that an insurance can pay. It will therefore be difficult to ask clinicians for the statistics on how often they misjudged the prognosis of very severely brain-injured patients, assumed they have the medical knowledge. It was reported about a young girl who suffered a spinal cord injury because of wrong treatment in the hospital [18] and the parents are still fighting at courts to get money for treatment. The main problem of organ donation is not the donation itself, but the by far out-of-date repair treatment in very severe brain injury. An out-of-date part of medicine interferes with proper organ transplantation.

At an international conference in pediatric brain repair there was no interest to get informed about new developments in brain repair. Apart from lawyers and economy students nearly nobody was interested to come to the poster of the Author for information and discussion (**Figure 25**). There is no interest to repair the brain through movement-based learning because no money can be earned. In the former East-Germany (or Russian occupation zone) there was strong interest in the research project of the author (see below), because no big money could be earned with patients. With fall of the Berlin wall, the interest vanished.



**Figure 25.** Poster of the author Schalow G (Number 38) at the international conference IPBIS2018 in Belfast 2018: Pediatric acquired brain injury repair. The poster is not especially good because of lack of money. But the repair progress of the nervous system in children can clearly be seen. It is also shown that human anatomy and physiology is needed for repair. The participants of the poster session went a long way around not to give the author a chance to talk to them. No conference participant wanted to try out this special CDT device or to get a publication.

### **Repeated transient coma recovery 8 months after injury when exercising 40 min on a special CDT device without consequences for hospital treatment**

The author was asked for consultation and a second opinion to the patient Georgios after being 8 months in coma following a car accident. The author tried to communicate with the 25 year old patient via eye blinking and hand grip power. The patient did not communicate by eye blinking and the author could not feel any activation of hand and finger muscles when giving the command to chase the hands. Then the patient was transferred to the wheelchair and the legs were mounted to a special coordination dynamics therapy device (**Figure 26A**). The author took the hands of the patient and turned together with him the handles. During the passive exercising, the patient opened the eyes strongly and the face expression changed. He looked more alert. Suddenly after 20 min of exercising, arm muscle contractions occurred in the flaccid arms. It seemed as if the patient blocked the movement exerted by the author.

When patients with severe brain injury try to help during exercising, their CNS has stress and reacts with spasticity. Even though such patients want to help during exercising, they block the movement unwantedly.

After exercising 40 min excluding a few breaks of 5 min, the author was checking ones more the consciousness. He took ones more the two hands of the patient and asked to shake the hands. Now the author could feel finger muscle contractions and could see also the small fingers moving. Georgios had become able to contract hand muscles on command first time after 8 months. Then the author asked the mother to do the same procedure (**Figure 26B**). The patient Georgios contracted hand and finger muscles on command as with the author, but did not want to let the mother's hand free as if he would need her hands for safety/anxiousness reasons. Obviously, Georgios had reached the minimally consciousness state [30] at least in the short-term memory.

Next day the author proved again the consciousness state of the patient. The important question was whether the patient had reached the minimally conscious state permanently or only transiently. The patient did not communicate. He had lost the minimal consciousness state. But when exercising again on the special CDT device for 40 min, the patient could communicate again with hands and fingers as the day before.



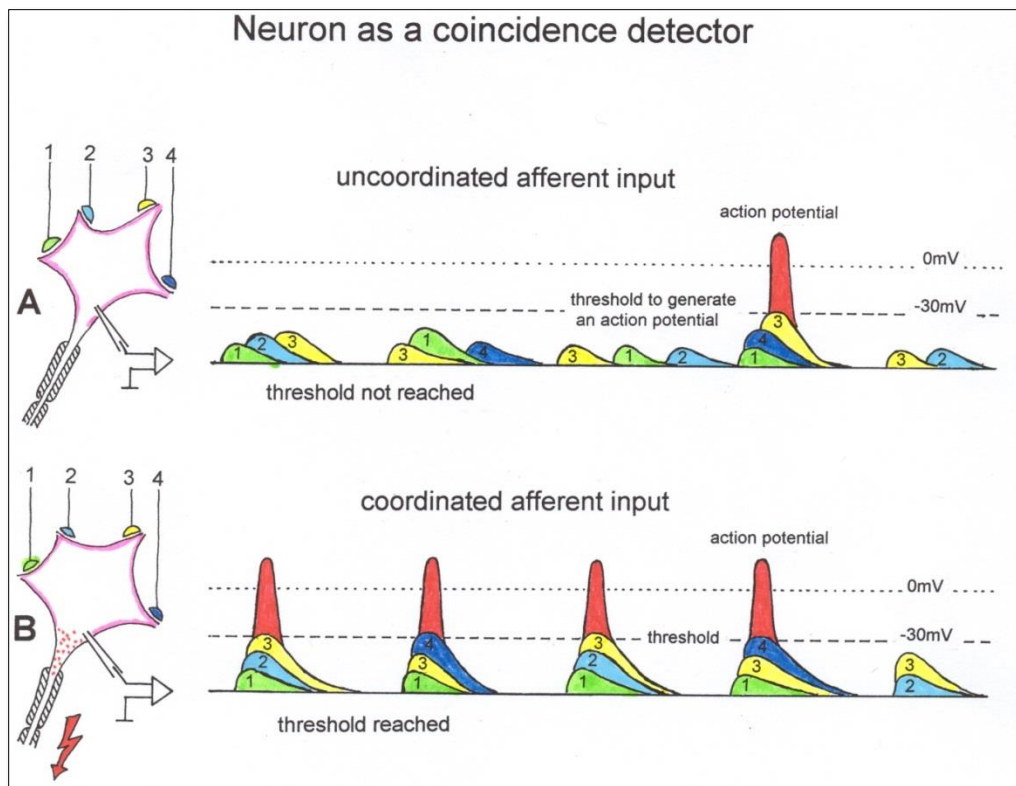


**Figure 26.** A) Exercising of the author with the coma patient Georgios on a special CDT device. The mother of the patient is supporting the head and one leg. B) The mother of the patient Georgios during communication with her son by hand functions. The father is supporting the head, because of missing trunk stability.

This training and communication with the coma patient Georgios is for several reasons important. Firstly, the coma patient Georgios could be brought out of coma repeatedly, which was not possible in the 8 months of conventional therapy before. With conventional physiotherapy his face expression became also livelier as the mother said, but he did not come out of coma. Efficient integrative (coordinated arms and leg movements) neural therapy seems to be needed for this patient to reach consciousness. At this stage of repair of neural network organization, it was only possible to reach consciousness transiently when exercising on the special CDT device. Secondly, consciousness seems to be an integrative neural network state of the CNS. Thirdly, it may be that in this patient Georgios the injured 'Ascending reticular activating system' (ARAS) in the brain stem was activated more efficient when exercising with him on the special CDT device than by conventional physiotherapy. The coordinated movement induced afferent input made the network/pathway ARAS working better in the way that the network/pathway nerve cells reached the threshold earlier because of the more coordinated endplate potential input (**Figure 27**). Fourthly, with repeated exercising, the minimally conscious state may be reached first only transiently and only later the consciousness state will become permanently. Most patients with less severe brain injuries

stay continuously conscious once they have left the coma state. But in the case of Georgios, the minimally consciousness state was reached first in the short-term memory. Also, the mother of the patient Manolis [16], who lost approximately 50% of the brain, reported that first she could communicate with her son only after exercising on the special CDT device. Further, the mother's voice seems to be most efficient to reach the patients consciousness. Fifthly, the patient Georgios has a good prognosis to reach full consciousness and a meaningful life if CDT is administered continuously, because his lost amount of nervous tissue was small in comparison to that of Manolis. In the case of Manolis, the radiologist argued that it is difficult to find nervous system tissue in the brain which is not damaged; in the case of Georgios the physicians thought at the beginning that, based on the MRI, Georgios will soon wake up and walk out of the hospital.

The physicians and the physiotherapist of that hospital did not want to apply CDT and the parents were afraid to take the patient home, against the advice of the author. The patient is still in the permanent coma and will probably stay in coma for ever, die or his body will be used for organ donation.



**Figure 27.** Neuron operating as a coincidence or coordination detector. **A)** Afferent input is reaching rather uncoordinated the cell soma. Only sometimes an action potential is generated, because the threshold of action potential generation is mostly not achieved. **B)** The action potentials in fibers 1 through 4 are reaching time-coordinated the dendrites or the cell soma. The postsynaptic potentials add up and the threshold is achieved at approximately  $-30\text{mV}$ , and action potentials are generated time-coordinated at the axon hillock. In the real CNS mostly, many smaller postsynaptic potentials will contribute to the generation of an action potential and passive conduction from the dendrites to the cell soma has to be taken into account. Coordinated afferent input may thus induce or enhance (coordinated) communication between neuronal network parts following CNS injury.

### Research across the Berlin Wall

This research project was started in 1983 in Finland. Some pre-experiments were done before to see whether the single-nerve fiber action potential recording method was working in animals. At the Neuropathology Department of Turku University, the anatomy of the spinal cord was clarified within 2 years. When there was nobody who could be interested in measuring single-nerve fiber action potentials in Finland, the author changed the country for continuing the research project to repair the human CNS.

The author (German) thought that neurosurgeons of the "Deutsche Demokratische Republik" (GDR) could be interested to cooperate in such a research project, because researchers and clinicians from countries across Eastern Europe wanted at that times to have contacts to the West. Living in West-Berlin, the author had to pass via certain roots (transit ways) through the GDR to reach West-Germany or other northern European countries. Once he

left the transit route to the North (forbidden area for transit) and went to Rostock University and asked for the Chief of the Neurosurgery Department, he was told that there was only a Neurosurgery Department at Greifswald University, situated in the North of West-Berlin. The author wrote to the Chief of the Neurosurgery Department (Prof. Lang, see co-author of [22]) and he was interested. Subsequently, a research cooperation was started to repair human CNS injury between a subject from West-Berlin and a professor from a university of the GDR.

On the way from West-Berlin to Greifswald the author had to cross the border (the Berlin Wall) for leaving West-Berlin. He used the boarder cross at Stolpe (not Checkpoint Charlie). Especially the wall at the 'Brandenburger Tor' (**Figure 28**) was nasty to see for the author because before the building of the wall he used to walk through it to reach the 'Staatsoper Unter den Linden' or the 'Komische Oper'. Because of lack of money he changed 1 DM (Westmark) into approximately

4 Mark of the DDR (Ostmark) und could then afford to

visit quite often the operas.

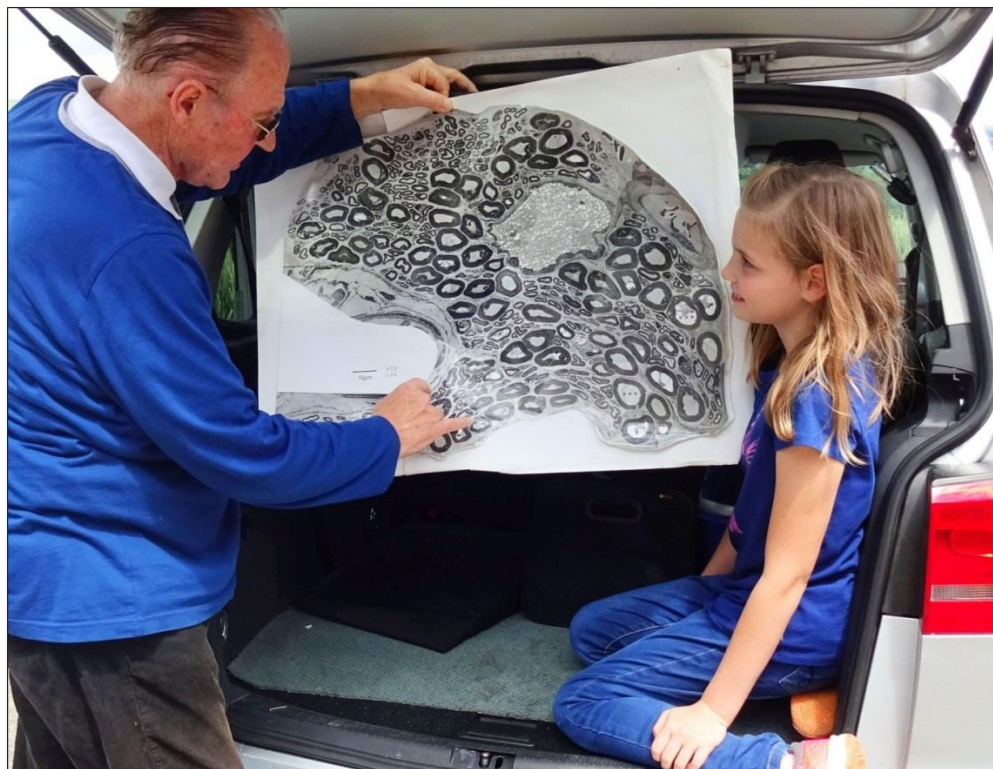


**Figure 28.** Berlin wall in front of 'Brandenburger Tor'.

On the way to the North he passed two Russian barracks and a Stalin monument. Sometimes he was stopped by Russian military police and was asked whether he had seen any escaped Russian soldiers. But he was not inspected. There was supposed to be also a Russian concentration camp close to Neubrandenburg where members of the "Hitler Jugend" were put to. Nobody had told more details because of fear. If denounced, one was also put to that concentration camp and this was a way of no return. Maybe also the father of a later president of Germany (Joachim Gauk) was put there. In West-Berlin the author lived close to an American army barrack (Finkensteinallee) and sometimes he saw American military police. He felt safe when he saw American soldiers, because when he was in an orphanage, the American soldiers helped the orphanage and especially at Christmas. We children got then chocolate and other nice things to eat. His first ice cream the author got when he was 14 years old and was invited to the American barracks.

At the beginning of the cooperation between the author from West-Berlin and the professor from GDR, the author had to pay 25 "Mark der DDR" per day for using research facilities. Then later on, he had to change 25DM West

into 25 Mark der DDR (Zwangsumtausch). Even later on he got for one-year research money from the Ernst-Moritz-Arndt University of Greifswald (900 Mark der DDR). The cooperation and the funding were not only helpful in order to progress the research project but was also politically interesting. Since the GDR wanted that West-Berlin was seen as an independent country, which the administration of West-Berlin and West-Germany did not want. For sure, the Germans did not want to have their country split into different parts and get their culture partly destroyed. Therefore, it was officially impossible to have a research cooperation between a researcher from West-Berlin and a professor from the GDR. Still it was possible. Because of this unusual situation, some persons, the author worked together with in Greifswald, thought that he was an unofficial member of the secret police (inoffizieller Mitarbeiter der Staatssicherheit (Stasi)), which they told him after the fall of the Berlin wall. There was not any political pressure put onto the author, even though he felt some pressure from the surrounding. A very interesting fact was that the author was told that there were reports written on him and it was clear that not only his research work was judged.



**Figure 29.** The author is showing the patient Sophie the cross section of a thin nerve root (ventral S4 nerve root). This was the situation how the author showed and explained the repair of the nervous system to border police when he crossed the border from West-Berlin to the GDR (East Germany or better Russian occupation zone). The border policeman was, of course, standing at the car and not sitting in the car. This sitting position of Sophie looks relaxed and smart after a partial repair of her CNS (cerebral palsy [28]). The border police had the order to control the cars for 10 min. Instead of an examination, the author explained his research project at Greifswald University.

Since at the beginning he had to pay for every day being in the GDR, he travelled quite much from West-Berlin to Greifswald and was of course inspected every time, which was unpleasant. With time, the border police started to know the author quite well and instead of inspecting him, he explained them what research he was doing in Greifswald University. Most impressive for them was to look at cross-sections of nerve roots of about  $1\text{m}^2$  size (**Figure 29**) to see what a terrible lot of axons of different sizes (only the myelinated ones can be seen) are contained in a thin nerve root of hair thickness.

Still the crossing of the boarder was stressful, because sometimes he was examined seriously to see whether he transported forbidden things. Of course, there were small things the author brought to Greifswald for friends who helped him to organize the research project, as for example a pocket calculator, glutaraldehyde or epon for working with the electron microscope. For measuring single-nerve fiber action potentials from brain-dead human cadavers (HTs), he needed for the start an anesthetist for sufficient ventilation and medication, then he needed a neurosurgeon to do the laminectomy, which is not simple in brain-dead humans and he needed a

physician or medical student who helped him with the recording. When working with HTs, the mental load is high and one needs a lot of motivation. “The ratio tells you that you are working on a cadaver, but the feeling tells you that you may kill a human being”, because the heart is still beating. When the artificial ventilation of an HT is terminated, the heart may beat for another one to two hours. The heart is not using only ATP; it can also work with ADP for safety reasons. A pathologist would never start an autopsy on a cadaver in which the heart is still beating. The author got a lot of help in Greifswald to realize the research project. The measurements in HTs were the essential step forward to make a repair of the injured human CNS possible. Even though many scientists and clinicians of the GDR expected that the success could only come on the long term, the author got a lot of support. The only country in the world which really supported this research project was the former GDR (Deutsche Demokratische Republik). But all decisions were legally. The DFG from West-Germany, for example, decided that this research project was not ethically, most likely without using any ethical committee. In Greifswald an ethical committee was formed to decide whether the

research, using also HTs, was justified. The committee decided that this research was ethically justified and the author could continue with his research. Since there was a lack of dialyze filters (for financial reasons), kidneys had been explanted excessively from HTs in the GDR with permission of the relations. The author got those HTs which could not be used for kidney removal as for example when the former patient had an infection. Further, an explanted kidney can help one patient. Qualified medical research on HTs may help millions of patients. Also, when the author tried to further clarify the innervation of the human urinary bladder everything was on legal terms. For clarifying human anatomy under the microscope, he needed fresh cadavers from young persons and those ones one can get in the forensic medicine. A forensic autopsy was controlled in the GDR by a lawyer to see whether the autopsy was performed on legal terms. After the termination of the autopsy, the professor of the forensic medicine explained the lawyer the authors research project and asked whether it was allowed that he can do further dissections. The lawyers gave the permission.

Further details of the adventure to do the medical research for a repair of the human brain are given elsewhere [19]. Anyhow, the recordings from single-identified neurons of the rather natural functioning human CNS brought the essential progress for repair.

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