Archives of Clinical and Medical Case Reports
doi: 10.26502/acmcr.96550057

Volume 3, Issue 2 **Review Article**

Permanent Coma Patient Re-Learned to Speak via Coordination Dynamics Therapy

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Received: 05 January 2019; **Accepted:** 01 February 2019; **Published:** 01 March 2019

Abstract

Following an extreme severe brain injury in a car accident, a 22-year-old male patient lost approximate 50% of the brain and switched into the permanent coma state. One year after the accident coordination dynamics therapy (CDT) was started with 20 hours per week. Following 3 years of CDT he started to reach slowly the minimally consciousness state. Following 5 years of CDT, he was fully out-of-coma. Some movement functions re-appeared and he became able to communicate with the surrounding. Following 5.5 years of CDT he could move better and say the word 'ma' instead of mama. It was hoped that he could re-learn a few words. Through 5.7 years of intensive CDT, he rather suddenly became able to speak again. He could precisely repeat every word in English or Greek (mother tongue), but he was not able to have a conversation. The cognitive functions were still missing. Following 6 years of CDT the patient Manolis became able to exercise a bit on the special CDT device by himself. His higher mental functions, including memory, improved and he became able to communicate via speech. Because of the speeding up of the repair, when the patient was fully out-of-coma, more brain repair seems possible through further intensive CDT. It is discussed with respect to repair in spinal cord injury and cerebral palsy why such tremendous brain repair was possible.

Keywords: Coma Patient; Brain injury; Coordination dynamics therapy; Neurophysiology

1. Introduction

It has been reported before about this patient Manolis who could be brought fully out of the permanent coma through 5 years of coordination dynamics therapy (CDT) [1, 2]. Because of the importance that such a severely brain-injured patient could even re-learn speaking and improve his cognitive functions, it is reported here again about his brain repair achieved through a long-lasting intensive CDT.

1.1 Scientific basis coordination dynamics therapy (CDT)

CDT is an efficient movement-based-learning treatment to repair the human brain and can also be applied to coma patients [1]. CDT consist of exercising on a special CDT device (Figure 3A) to improve the phase and frequency coordination of neural network organization and the training of movements like creeping, crawling, walking, running, jumping and old-learned movements (for example Figure 6), if possible, so that other parts of the CNS can take function over by plasticity. The scientific basis of this new efficient treatment is the human neurophysiology and especially the electrophysiology. With a new recording technique, the "single-nerve fiber action potential recording method" [3] and the single-motor unit "surface electromyography" (sEMG) neural network organization of the central nervous system can be analyzed under physiologic and pathologic conditions and treatment developed.

1.2 Repair of the impaired phase and frequency coordination among neuron firings

With the single-nerve fiber action potential recording method one can record at the neuron level simultaneously the natural impulse patterns, from sets of single-nerve fibers, running into the CNS (spinal cord) and leaving it [4, 5] (Figure 1) and analyze human neuronal network organization at the single-neuron level [6]. An important finding is the phase and frequency coordination among neuron firings [6], which becomes impaired following injury [7] and has to be repaired. This phase and frequency coordination can also be observed non-invasively when performing sEMG from spinal cord injury patients when a muscle is only innervated by a few motoneurons (Figure 2). The organizations of motor programs can be followed up [8] and the coordinated firing of motor units nicely be seen (Figure 2). When exercising coordinated movements, especially on a special CDT device (Figures 3A, 14), there is learning transfer [9] from movements to other movements, urinary bladder functions [10], speech induction [1] and higher mental functions [1].

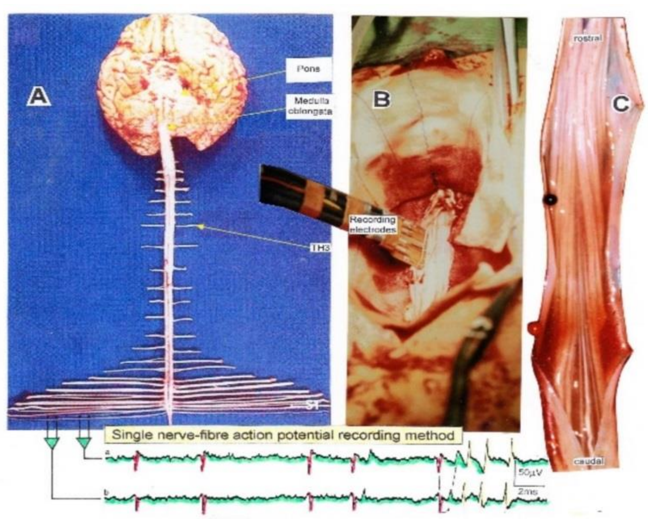

Figure 1: Layout of the recording of single-nerve fiber action potentials to analyze the self-organization of neuronal networks of the human CNS under physiologic and pathophysiologic conditions.

By recording with two pairs of platinum wire electrodes (B) from sacral nerve roots (cauda equina, C) containing between 200 and 500 myelinated nerve fibers, records were obtained in which single-nerve fiber action potentials (APs) were identified from motoneuron axons (main AP phase downwards) and afferents (main AP phase upwards). By measuring the conduction times and with the known electrode pair distance (10mm), conduction velocity distribution histograms were constructed in which the myelinated nerve fiber groups larger than 4μm could be characterized by group conduction velocity values. After the recording, morphometry was performed. Distributions of nerve fiber diameters were constructed and nerve fiber groups were characterized by the peak values of asymmetrical distributions. By correlating the peak values of the velocity distributions with those of the diameter distributions obtained for the same root, a classification scheme was constructed of the human peripheral nervous system. It became thus possible to record natural impulse patterns simultaneously from identified single afferent and efferent nerve fibers and analyze self-organizing mechanisms of the human CNS under physiologic and pathologic conditions [1].

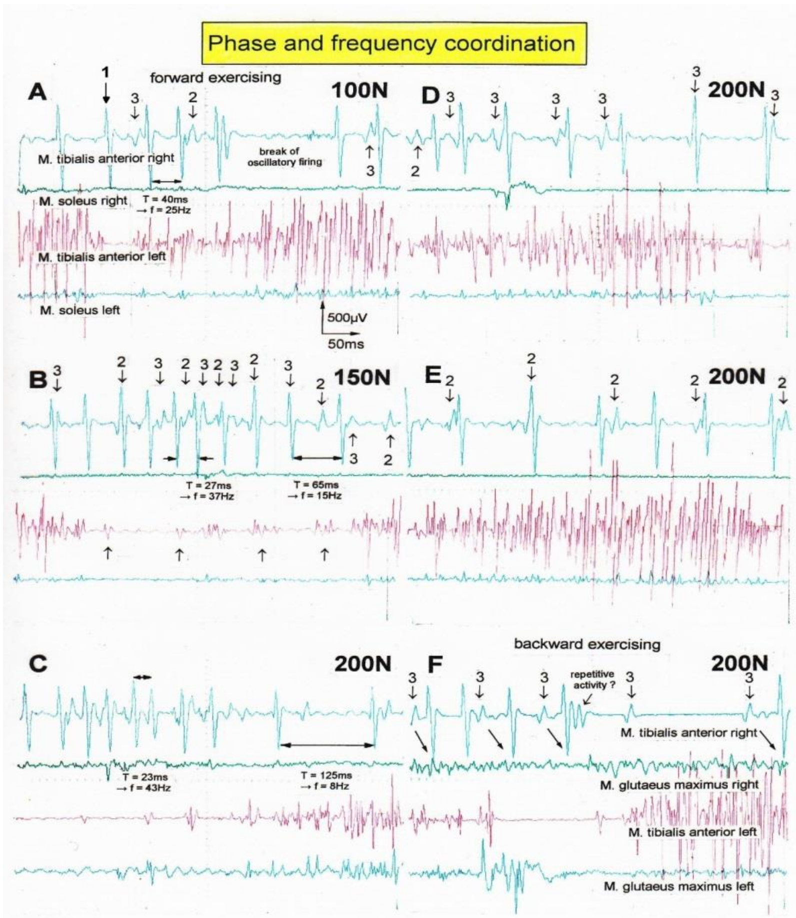

Figure 2: Recording phase and frequency coordination between oscillatory firing motor units (1, 2, 3; FF-type) by sEMG during the generation of a motor program when exercising on the special coordination dynamics therapy device at loads increasing from 100 to 200N. Oscillation periods (T) and oscillation 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.

1.3 Achieved CNS repair so far

It has been shown that CDT can improve or repair central nervous system (CNS) functioning after stroke [12], traumatic brain injury [13, 14], spinal cord injury [15, 16], cerebellar injury [17], cerebral palsy [18], hypoxic brain injury [19], in Parkinson's disease [20], spina bifida (myelomeningocele) [21] and scoliosis [22]. Speech had been induced and improved in a patient with severe cerebral palsy [1] and urinary bladder functions were repaired in patients with spinal cord injury [23, 24]. In patients with cancer, especially breast cancer, cancer growth inhibition could be achieved via CDT [25]. The cardio-vascular performance was repaired in a patient with a very severe brain injury (Manolis) during the first years of CDT [26]. It seems therefore that CDT can improve CNS functioning in every case, even in the extreme case, and since the nervous system is involved in nearly all body functions, CDT can improve/repair human health in general.

2. Method

2.1 Applied movements

The movement-based learning therapy of the coma patient consisted mainly of exercising passively on a special CDT device for improving mainly the impaired phase and frequency coordination (Figure 3AB) and sky-walking (Figure 3C-D) to train the walking and the upright position for counter-acting an orthostasis syndrome. Additional conventional physiotherapy and speech therapy were administered to the patient. When the patient was fully out-of-coma, additional movements were trained as playing with a ball or activating old-learned movements like playing violin. When the speech was repaired, all kinds of communication were trained.

Figure 3: Movements performed with a 23-year-old male patient in the vigilant coma by the family members. All movements were passively performed, because the patient was in coma. A, B. Exercising on the special CDT device in the lying position (both hands are fixed) and sitting position. C, D, E. Exercising on the sky-walker.

2.2 Motor learning and problem solving through error-elimination

Learning occurs as a modification of existing structures and processes. By inducing trial and error-elimination processes [30] in subunits of the changing nervous system, optimal repair may be achieved. To teach the injured CNS to repair itself by trial and error elimination processes, the CNS has, in similarity to development, to recognize through CDT, which sub-networks, regulation units or sub-loops are not functioning properly or missing and to repair them by error-elimination, including the possibility that other parts of the brain partly take functions over and sub-networks are built anew to a limited extent.

3. Results- Case Reports

3.1 Recovery situation before CDT was started

The 22-year-old Manolis suffered an extreme severe brain injury in a car accident. In the accident a metal shard went into his right brain and nervous tissue was lost. The severances of the injury can partly be seen in Figure 4. After surgeries in a university clinic, he was sent to a conventional rehabilitation center. At the beginning of rehabilitation, his relations could communicate with him via eye blinking. After a few months this communication was lost. The pathologic processes seemed to have won against the physiologic repair. The family did not want that Manolis would die. They took him out of the rehabilitation center and started CDT at home with a lot of vegetative nervous system problems at the beginning of therapy as for example the blood pressure [1, 26].

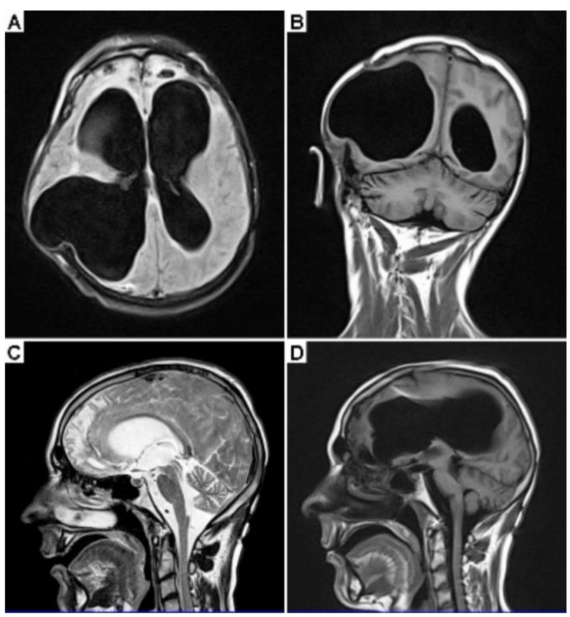

Figure 4: MRI of a 23-year-old male patient with a very severe traumatic brain injury. The pictures were taken one year after the car accident. Since a metal shard went into the brain during the accident, some brain tissue had to be removed. A shunt was installed to regulate brain pressure. Because of the loss of nervous tissue, the ventricles became enlarged; they look like in cases of hydrocephalus. Many parts of the brain were damaged during the accident, including both frontal lobes (A, C). The artifact from the shunt can be seen in 'C'.

Realizing the tremendous damage of the brain of Manolis (Figure 4), the Author himself had doubts whether it would be possible to get him out-of-coma through CDT. Based on his experience with rehabilitation, the neurosurgeon, who operated the patient after the accident, predicted that the family members should be happy if they could keep the health level of the patient (Figure 5A), which means staying in the permanent coma for ever till he would die on a complication within approximately 5 years.

3.2 Repair through 5-years-CDT

Following 3 to 5 years of CDT with 20 hours therapy per week, Manolis came via the minimally consciousness state [11] out-of-coma. When the Author saw him first time to lift his head and kissed the mother, after 4 years of CDT, he had the feeling that Manolis raised from the dead. After 3 years of CDT, the permanent coma patient slowly reached the minimally consciousness state [11]. After 5 years of CDT, six years after the accident, Manolis was fully out-of-coma. He could play and laugh with the mother, sit freely on bed and could just keep the crawling position. He could also sit freely, but he could not stand and walk. He could generate sounds, but could not speak. The left hemisphere, where the main speech centers are, was not damaged that much. It might therefore be possible that the patient could re-learn a bit to speak. After being out of the coma and being able to move a bit on volition the head, trunk and right arm, it seemed that the repair of the former coma patient speeded up. But there were a lot of spasticity and pain problems and whether he could ever reach a meaningful life state was unclear.

Figure 5: (A) Picture of the 23-year-old patient being 1.5 years in the vigilant coma following a car accident. The impression in the face does not look as healthy as the one in the picture made 2 years before when he was in the army; (B)The facial expression of Manolis following 5.7 years of CDT during counting in English the numbers one-two-three-four-five. Note the improvement of the expression of his face.

3.3 Repair through 5.5-years-CDT

Following 5.5 years of CDT, 6.5 years after the accident, Manolis became able to activate old-learned movement patterns as eating and playing partly violin (Figure 6). Old-learned movements are helpful for CNS repair, because they are stored in the cerebellum or other lower parts of the CNS. If for example patients could ride a bicycle before the accident, this movement pattern should be used, if possible, also for repair. Manolis could still not speak. When being pushed to say mama, he succeeded to say ‘ma’. Maybe he could re-learn with further therapy to say ‘yes’ and ‘no’ and ‘mama’ and ‘papa’, especially because it seemed that the brain repair speeded up. But his repairing brain through CDT found another way to speech.

Figure 6: Preparations of the brother (A) to bring Manolis into a proper violin playing position. Note in B, how nicely Manolis can use the right fingers to generate the sound (frequency of up and down finger movements around 5Hz). When playing violin (C), his face looks quite healthy. The fingers of the left hand cannot change the sound position because of the lost right hemisphere.

3.4 Repair through 5.7-years-CDT

Through 5.7 years of CDT, 6.7 years after the accident, Manolis became nearly suddenly able to speak again, which was completely unexpected. He could repeat every word in Greek (mother tongue) or English. The pronunciation was good. The mother said, that when her son became able to speak at the 20.7.2018, she had the feeling to have got wings for going on with the therapy. When counting with a girl English numbers, his facial expression looked quite nice (Figure 5B) in comparison to the facial expression after the accident (Figure 5A). Manolis liked it to be helped by children and had less spasticity then. When playing with one of the sisters, he could also smile (Figure 7). Even though Manolis had re-learned to speak, a discussion was not possible because of the still missing cognitive functions.

Figure 7: Manolis during playing with a sister. As can be seen from the expression of his face, he enjoyed it. He could smile again.

3.5 Repair through 6-years-CDT

Following 6 years of CDT, 7 years after the accident, Manolis became able to turn a bit on the special CDT device by himself (Figure 8). According to experience, when patients become able to exercise by themselves on a special CDT device (before the patient was exercised passively), further functions become repaired. Cognitive functions and memory slowly re-occurred in Manolis. He started to remember songs from before the accident. When showing him numbers he could say the numbers and count also a bit (Figure 9A). Real communication started to become possible. For example: "Why don't you use also the left hand for exercising" – "because I have pain in the left arm". He became able to eat by himself; artificial nutrition was reduced. Manolis got strong muscle power in the right arm and hand and became over-active. All the time he moved about and played with the right hand to get contact and input (Figure 9B).

Figure 8: The patient Manolis with a very severe brain injury during exercising by himself on the special CDT device. He could volitionally move the right hand and both legs. The motivation for exercising by himself changed all the time in spite of the continuous instructions of the mother.

Figure 9: (A) Manolis during reading and counting numbers; (B) The patient during playing with the right hand with a cousin.

3.6 Repair of the left body side

A further big problem of the now conscious patient is the repair of the left body side due to the mainly lost right hemisphere (Figure 4) in some similarity to stroke patients. The pyramidal tract (lateral corticospinal tract) from the mainly lost right hemisphere (Figure 10) is mainly atrophied and little activation seems to come so far from left hemisphere via the left uncrossed anterior corticospinal tract (Figure 10). How much the left hemisphere can take function over by plasticity via the uncrossed anterior corticospinal tract (Figure 10) has to be seen. Manolis could move a bit the left leg during exercising on the special CDT device. He could also move a bit the left arm and hand. But he had a lot of pain with the movement, mainly from the elbow joint (osteophytes had grown). Two years ago, one had to see the pain in his face. Now he was clearly telling you when he had pain and he was trying to avoid it. Still it has to be tried to exercise the whole body so that the nervous system is not giving up the left body side in similarity to stroke patients.

3.7 Continuation of CDT

With Manolis the 20-hour therapy per week is continued. It has to be seen what further CNS repair can be achieved, including cognitive functions, motor, urinary bladder, bowel, and sexual functions. When exercising on the special CDT device bladder functions are repaired. Additionally, the mother is training already with Manolis the right leg and foot functions by kicking a ball (Figure 11) since bladder functions are closely related to leg and toe functions in the sensory-motor cortex (Figure 10).

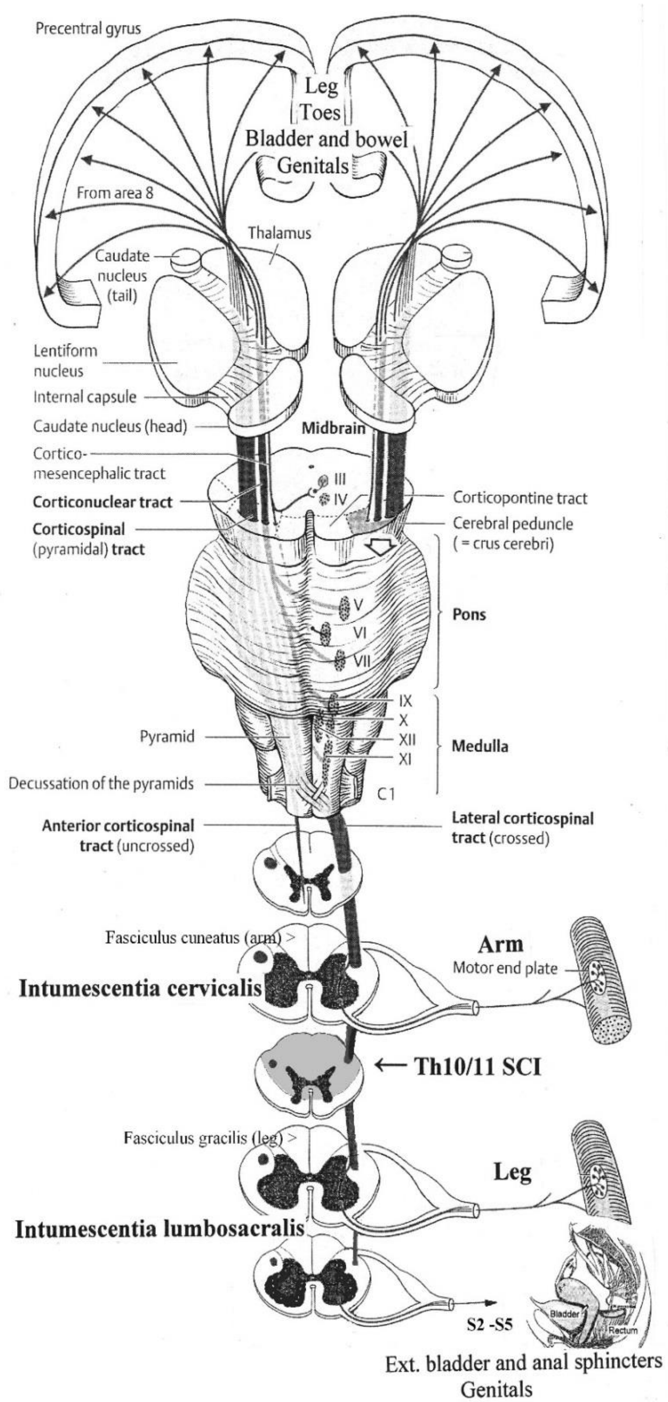

Figure 10: The whole CNS is involved in the repair of the brain and/or the spinal cord injury. Note, leg, toes, urinary bladder, bowel and sexual functions are closely related in the sensory-motor cortex. With the coordinated activation of legs and feet bladder, bowel and sexual functions may be repaired by learning transfer [9, 10].

Figure 11: The now 29-year-old patient Manolis with a very severe brain injury concentrates to kick the ball with the right foot repeatedly. Note, he is fully included in the family life.

The training of Manolis looks now like the training of a normal brain-injured patient with all the deficits from the brain injury. But one should not forget, Manolis was 4 years in the coma and most likely would have died or would have stayed at best in the coma forever with conventional physiotherapy. Through 6 years of CDT, 7 years after the accident, with 20 hours therapy per week he is back to life and fighting even a little bit by himself for further brain repair.

4. Discussion

It was shown above that, based on a new development in human neurophysiology, the human nervous system could partly be repaired by a new treatment, called coordination dynamics therapy (CDT) in a patient with an extremely injured brain. Even the speech could be re-paired and the higher mental functions improved. Manolis could precisely repeat every word in English or Greek and started with further repair to use the speech for communication. During instructive training, when exercising on a special CDT device (Figure 3A) he was even counting 1-2-3, in similarity to a self-instructive training. He realized the situation around him. Without telling him, he understood from discussions of the Author with the mother that the Author was working on a scientific paper. It seems possible that he can reach the meaningful life state. But whether he can start to work again is unclear.

4.1 To get the patient out-of-coma is the most difficult step of brain repair

Actually, two important steps were achieved in this formerly permanent coma patient. The first step was to get him fully out-of-coma and the second to make him speak and communicate again. A third step would be to reach the meaningful life state. The very big therapy effort was to get him fully out of the coma through approximately 5-years of CDT. The speech, including memory and improvement of cognitive functions, were achieved with less effort, namely with approximately one year of CDT.

4.2 Reconnection of speech networks

The rather sudden occurrence of the speech makes it likely that the speech areas were in principle operational. But they had to be re-connected functionally to the whole brain organization again (re-connection treatment). The improvement of the phase and frequency coordination, in the deepness of the complexity of neural network organization (in the association fields), may have contributed to the activation of the speech pattern in some similarity to the activation of the old-learned pattern 'playing violin' (Figure 6).

4.3 Epigenetic regulation for repair

Such tremendous repair achieved via CDT, especially in the permanent coma case, seems only possible if the epigenetic regulation for repair had been substantially activated by movement-based learning. CDT had induced the stimulation of those pathways that regulate neural network repair. Epigenetic mechanisms, stimulated by physiologic network activation, are likely key players within signaling networks, as DNA methylation, chromatin remodeling and small non-coding RNAs superfamily and are required for the fine-tuning and coordination of gene expression during neural network repair by learning. The complexity of the epigenetic regulation is tremendous. Figure 12 shows steps of epigenetic regulation induced by specific and coordinated physical activity, namely movement-based learning.

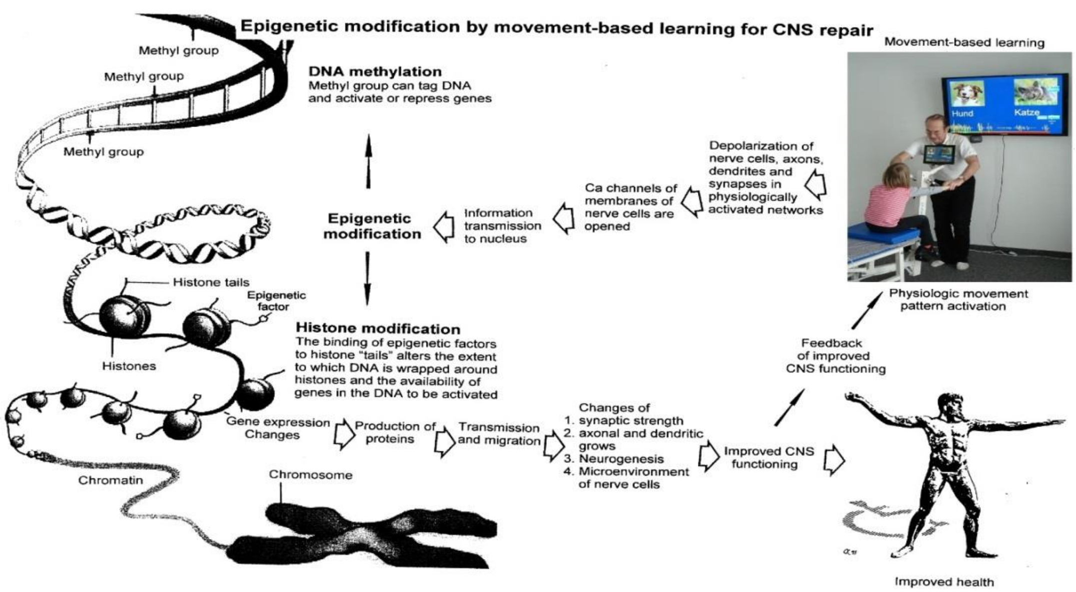

Figure 12: Epigenetic regulation for repair by movement-based learning. CDT-induced stimulation of the pathways that regulate neural network repair is a proven therapeutic and preventive tool. Epigenetic mechanisms, stimulated by physiologic network activation, are likely key players within signaling networks, as DNA methylation, chromatin remodeling and small non-coding RNAs superfamily 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.

To generate repair in the nervous system, it is likely that permanent changes in gene expression patterns are achieved through permanent changes in chromatin remodeling without changes in DNA sequence. The concept of chromatin remodeling addresses a key challenge of how stable changes in gene expression are induced [27] in neural networks to produce long-lasting changes in repair. DNA methylation is one of the many epigenetic modifications that can alter gene expression. Dynamic and reversible DNA methylation may be essential for learning and memory formation and could transmit repair influences onto adult neurogenesis. Understanding the complex epigenetic regulation of neural activity and adult neurogenesis is integral to designing therapeutic approaches to restore neurogenesis and cognitive functions. It will also give a tremendous insight into understanding how certain environmental or pathological influences, such as stress, physical activity, depression and epilepsy regulate adult neurogenesis [28]. Excitation-neurogenesis coupling in adult neural stem/progenitor cells [29] can be achieved through depolarization of membranes generated by physiologic movements.

4.4 Other patients could benefit from the reported success

There are many more patients in the permanent coma who could be brought back to life through CDT. If there is no communication possible, the severance of the injury and the repair stage can often be seen in the expression of the face. In the case of Manolis, compare Figure 5A with Figure 7. Michael Schumacher (Formula 1) probably had a less severe injury than Manolis and has therefore a good chance for recovery if CDT would be administered to him. Christopher Reeve could probably still live if CDT would have been administered to him, because CDT repairs urinary bladder functions including the kidneys [9,10]. The first step to get the patients fully out-of-coma seems to be the biggest step with also the biggest mental load on the therapists. With conventional physiotherapy such severely brain-injured patients have no chance to get back to life because of the too low treatment efficiency.

Figure 13: (A) The 6-year-old Nefeli after suffering an incomplete spinal cord injury (Th10) by medical malpractice. (B) Nefeli after eight months of conventional children rehabilitation in Switzerland (Affoltern). Sticks and orthosis were needed. (C,D) Ten-year-old patient Nefeli with an incomplete spinal cord injury Th10 (marked in Figure 10) after six months of coordination dynamics therapy. At school she can walk again and can write at the white board.

4.5 Repair through long-lasting chain of events of trial and error elimination processes are also needed

But why could such an unbelievable repair achieved in Manolis and not with other patients treated with CDT so far? The patient Nefeli, who suffered a spinal cord injury (Figure 13A,B) following a cancer operation by medical malpractice, improved strongly through CDT. Urinary bladder functions could mainly be repaired and she re-learned to walk (Figure 13C,D) with deficits in performance and stability. There was even some regeneration of the spinal cord in the age of 10 and 11. But then the spinal cord regeneration arrested. Also, the cerebral palsy girl Sophie (Figure 14) with an atrophy of the cerebellum and pons learned walking (Figure 15) and keeping balance and became fully continent. But the progress was so far not that large as in Manolis. The probable main reason is that to Manolis, with the very severe brain injury, the therapy was administered 6 years continuously with 20 hours therapy per week. Besides the efficiency, the treatment was administered at the limit continuously over 6 years. For organizational reasons such an aggressive, continuous and long-lasting treatment could not be administered to the girls Nefeli and Sophie being 9 and 5 years old, respectively, at the beginning of therapy. It seems therefore that the intensity and the continuous long-lasting of CDT makes the unbelievable progress possible.

Figure 14: Common training of Nefeli (SCI, Th10/11, lying device) and Sophie (Cerebral palsy, sitting device) to enhance motivation to train at limits. In the background (red instrument) the healthy brother of Sophie is training successfully to reduce the squint, not to need spectacles any more. The special CDT device (Middle) for measuring and therapy (int.pat.) is produced by the firm: Giger Engineering, Martin Giger dipl.Ing.ETH/SIA, Herrenweg 1, 4500 Solothurn, Switzerland, www.g-medicals.ch.

Figure 15: A,B. The cerebral palsy girl Sophie when trying to walk with her mother before CDT was started. She could not generate a walking pattern. Knees were overstretching (A) which blocked the walking pattern and she was immediately falling (B). C. Sophie (left) learned walking through CDT. When Sophie (cerebral palsy) and Nefeli (spinal cord injury) were training together (here walking), they motivated each other to fight more.

A likely explanation is that there are also long-lasting repairs which are only taking place if the whole chain of events is completed. If the repair is prematurely stopped, the chain of events has to start from the beginning again [30] and if there are only therapy periods of 2 to 3 months, then these long-lasting repair strategies never take place and the patient cannot benefit from these long-lasting repairs. The child development needs something like 17 years. But there are other possibilities for differences in repair when applying the same treatment as for example that different CNS parts have a different strength of repair. There seems to be some similarity between child development and brain repair because Manolis first re-learned to repeat every word and then he re-learned to connect the speech to the higher mental functions to allow speech communication.

4.6 Danger of modern euthanasia

In Germany a law is in preparation with which surgeons are allowed to remove organs from brain-dead-humans or other patients without permission in beforehand. Since it is a tremendous effort to let not drift a severely brain-injured patient into the permanent coma or brain death (in Manolis 5 years of CDT with 20 hours therapy per week) and nearly no money can be earned, the possibility exists that no big effort is undertaken to bring the patient back to life, but let him die and use then the organs, as for example the kidneys, for other patients. Money can be earned with the transplantation of organs. The possibility of modern euthanasia exists with such a law. The inefficient and 30-years-out-of-date physiotherapy supports this euthanasia because it is that inefficient that in very severe brain injury the pathologic processes win against the physiologic repair mechanisms. The rehabilitation has even problems in diagnosing the minimally consciousness state of severely brain-injured patients [11].

5. History of the Research Project

The Author is a private researcher in human neurophysiology and clinical research to repair the human CNS and is living and performing research on 1200 Euro. For the upper research project, it was impossible for him to get funding (including Christopher Reeve Foundation, Swiss National Fond and Deutsche Forschungsgemeinschaft) in the last 30 years, even though the Author studied electronics, theoretical physics and medicine and was post doc with Sir Bernard Katz, Huxley and Ricardo Miledi, Department of Biophysics, University College London. Obviously, to save life of patients or improve their health is not of interest for the world society if a new qualified treatment has to be used. At the international conference IPBIS2018 in Belfast 2018 "Pediatric acquired brain injury" there was no interest for repairing the brain of children. A physician, who treated Nefeli and Sophie (Figures 13, 15) in a rehabilitation center in Switzerland, even did not want to see the progress of his former patients through CDT!

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Citation: Giselher Schalow. Permanent Coma Patient Re-Learned to Speak via Coordination Dynamics TherapyArchives of Clinical and Medical Case Reports 3 (2019): 33-50