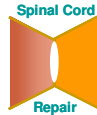




Speaker Abstracts

Thursday, February 12, 2009

Time	Title	Speaker	Country
Plenary Lectures:			
16:10-16:50	Rehabilitation Robotics: What Lies Ahead?	Prof. Dr. W. Zev Rymer	USA
16:50-17:20	The Patient is the Master: How to Control Rehabilitation Robots	Prof. Dr. Robert Riener	Switzerland
17:40-18:10	Spinal Cord Injury: Impact of Functional Rehabilitation on Clinical Recovery	Prof. Dr. Armin Curt	Canada
18:10-18:40	Neural Plasticity and Locomotor Recovery: Robotics in Research	Prof. Dr. Keith Tansey	USA
18:40-19:10	New Technologies for Upper Extremity Rehabilitation	Prof. Dr. Paolo Bonato	USA



Rehabilitation Robotics: What Lies Ahead?

W. Zev Rymer, Rehabilitation Institute of Chicago, USA

We have now witnessed more than 15 years of rehabilitation robotics in clinical rehabilitation, ranging from the use of elliptical trainers for walking recovery in stroke and SCI, to Lokomat applications for incomplete SCI and stroke, to various upper extremity robotic devices such as MIT Manus, Twrex/Armeo and other devices for stroke recovery. In addition, there are now several new multidegree of freedom robots for the upper extremity that are receiving preliminary testing.

To date, most of these robotic interventions have had measurable, statistically significant but rather limited therapeutic impact. So we are now faced with the problem of evaluating how best to deploy technically complex and often expensive systems in the face of increasing concerns about health care costs.

The particular quandary we face is whether it is more useful for patients to have limited access to advanced, but complex systems for their rehabilitation, or whether we should offer ready access to simpler less sophisticated systems that are more suitable for use in standard therapy clinics, or even in the home.

Most importantly, we need a theoretical framework, presumably linked to theories of motor learning and skill acquisition that allow us to make such choices rationally. This is because our capacity to rigorously test the various interventions available, using a suitable range of dosages, treatment intensities and durations is inevitably limited by cost and availability of clinical populations.

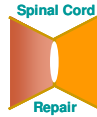
These issues will be discussed.



The Patient is the Master: How to Control Rehabilitation Robots

Prof. Dr. Robert Riener

In classical man-machine interfaces, the biomechanics of the human forms a part of the underlying control loop. However, integrating the human into the loop can be considered not only from the biomechanical viewpoint but also from novel psycho-physiological aspects. Biomechanical integration involves ensuring that the system to be used is ergonomically acceptable and “user-cooperative”. Psycho-physiological integration involves recording and controlling the patient’s physiological reactions so that the patient should always receive appropriate stimuli and is challenged in a moderate but engaging and motivating way without causing undue stress or harm. In this talk, I will present examples of biomechanical and psycho-physiological integration of patients verified with the gait robot Lokomat, the stepping device Erigo, and the arm therapy robot Armin.



Spinal Cord Injury: Impact of Functional Rehabilitation on Clinical Recovery

Dr. Armin Curt, MD FRCPC
Professor of Neurology
Assoc. Director of ICORD / Chair SCI Rehabilitation Research
University of British Columbia, Canada

Clinical recovery after a lesion of the central nervous system (CNS) can be attributed to mechanisms of functional compensation, neural plasticity and/or repair. The relative impact of each of these mechanisms after a human spinal cord injury (SCI) has been explored in a prospective European multi-centre study in 460 acute traumatic SCI subjects. Functional (activities of daily living and ambulatory capacity), neurological (sensory-motor deficits) and spinal conductivity (motor- and somato-sensory evoked potentials) measures were repeatedly followed over 12 months. In accordance with previous studies, complete SCI subjects (cSCI; n=217) improved in activities of daily living unrelated to changes of the neurological condition, while incomplete SCI subjects (iSCI; n=243) showed a greater functional and neurological recovery. The functional recovery in iSCI subjects was not related to an improvement of spinal conductivity, as reflected in unchanged latencies of the evoked potentials. This is in line with animal studies, where spinal conductivity of damaged spinal tracts has been reported to remain unchanged. These findings support the assumption that functional recovery occurs by compensation and by neural plasticity leading to a greater clinical improvement after SCI. These findings indicate the importance of advanced, controlled and optimized functional training that needs to be tailored to the specific condition of the patients.

Neural Plasticity and Locomotor Recovery: Robotics in Research

Keith E. Tansey, MD, PhD
Shepherd Center/Emory University
Atlanta, GA, USA

An assumption made with locomotor training, including that done with robotics, is that functional recovery of stepping will occur due to changes in activity in residual or re-organized neural circuits, that is, due to neural plasticity. Work in animal models of spinal cord injury (SCI) led to the application of locomotor training in patients with SCI and it was assumed that the neurological basis for any training effects would be similar across species. It is now acknowledged, that there are differences in locomotor training effects between animals and humans but little is known about any associated neural plasticity in either group. Since we utilize animal models to test treatments for human SCI, since locomotion is a common outcome measure, and since rehabilitation is often combined with new treatments, we must understand how locomotor recovery in animal models will translate to patients. We need to know if the neural plasticity caused by treatment in a rat will be sufficient to cause functional recovery in a human.

With complete SCI, locomotor function does not recover spontaneously in either animals or humans. With locomotor training, good stepping occurs in some animal models but not in humans. We have studied locomotor recovery in incomplete SCI in both rats and humans and have found contrasting results in terms of spontaneous recovery and recovery following locomotor training. These studies also suggest there are differences in associated spinal and supraspinal neural plasticity in rats and humans.

Rats with incomplete SCI spontaneously recover locomotion over 3-4 weeks after contusion injury but recovery plateaus in relation to the amount of spared white matter tracts in the cord. We found this spontaneous locomotor recovery occurs without an improvement in the ability for a supraspinal site, the hypothalamic locomotor region (HLR), to activate spinal circuits for stepping. We have now performed quadrupedal body weight supported treadmill training (BWSTT) on these rats and found that it neither improved open field locomotion nor the ability to activate stepping by stimulation of the HLR.

Humans with incomplete SCI show variable locomotor recovery but can show improved stepping after robotic BWSTT. We used fMRI to show supraspinal plasticity in the cerebellum was related to functional recovery of gait following locomotor training. We have evaluated patients for evidence of spinal plasticity by testing H-reflexes during gait before and after 3 months of locomotor training. We found that despite a training effect that improved the numbers of patients achieving over ground walking and improved walking speeds, locomotor training had no overall effect on H-reflexes.

In summary, in complete SCI, locomotor training causes sufficient spinal neural plasticity to generate gait recovery in animals but not in humans. In incomplete SCI in rats, locomotor training causes little additional spinal or supraspinal plasticity as no additional gait recovery is seen nor does supraspinal activation of stepping improve. In incomplete SCI in humans, locomotor training leads to functional recovery and is associated with neural plasticity that may occur more at supraspinal levels than at spinal levels.

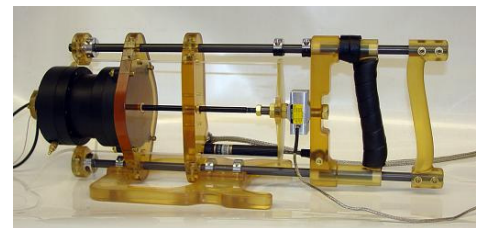
New Technologies for Upper Extremity Rehabilitation

Prof. Dr. Paolo Bonato, PhD

Dept. of Physical Medicine and Rehabilitation, Harvard Medical School, Spaulding Rehabilitation Hospital, Boston MA 02114, USA

Harvard-MIT Division of Health Sciences and Technology, Cambridge MA 02139, USA

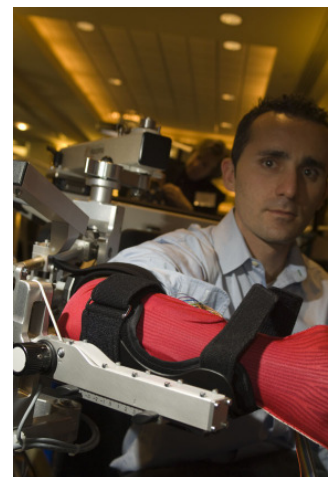
Mechanically-passive and robotically-actuated rehabilitation systems have gained the interest of researchers and clinicians as means to increase the duration, intensity and specificity of motor training. Via adoption of these technologies, clinicians hope to achieve larger motor gains and to contain the cost of labor-intensive interventions that are based on a one-to-one interaction between therapist and patient. Several systems were designed and implemented in the past to facilitate the performance of therapeutic exercises targeting the upper extremities. The first of these systems were focused on planar movements with emphasis on the control of the actuated components. The MIT MANUS is the most prominent among this first generation of rehabilitation systems. Over time, the focus shifted toward systems that are suitable to perform three-dimensional movements and toward designs that are suitable to decrease manufacturing costs, thus facilitating clinical adoption. An example of this second generation of upper extremity rehabilitation systems is the Armeo, a mechanically-passive device based on a previously designed system known as T-WREX.



Picture of an fMRI compatible system developed by Dr. Mavroidis' group at Northeastern University currently

Motor training performed by relying on the above-described technology facilitates improving quality of movement. Recent research indicates that short-term adaptations and long-lasting movement pattern modifications can be observed, modeled and tracked over time thus leading to new tools aimed to optimize the rehabilitation intervention. Improvements in motor patterns are associated with cortical reorganization. Early fMRI studies to assess cortical reorganization were based on the execution of simple and not well-controlled motor tasks. A new generation of fMRI-compatible systems is now emerging (see figure above) that has the potential to allow researchers to accurately assess cortical activity elicited by specific motor tasks. Other techniques based on noninvasive brain stimulation have been also utilized to assess cortical reorganization, but recently most of the interest for these techniques is focused on their potential use to facilitate cortical reorganization rather than to test for it.

Technology has also improved our ability to track movement using unobtrusive sensors at relatively low cost. This technology has the potential to allow clinicians to monitor the impact of motor recovery on the performance of daily activities as it can be used to assemble wearable systems capable of gathering data over extensive periods of time without interfering with the performance of activities of daily living. The same technology can also be utilized to facilitate the implementation of therapeutic protocols focused on specific aspects of movement and thus function. An example of this technology is shown in the figure to the right. A data glove originally developed by Dr. De Rossi's group was integrated into the Armeo system by the team at Spaulding Rehabilitation Hospital thus expanding the capability of the device to target the recovery of hand function. The glove system is accurate and relatively inexpensive thus allowing one to envision extending its clinical application to the home setting.



A subject during a testing session at Spaulding Rehabilitation Hospital using the Armeo system in combination with the



Speaker Abstracts

Friday, February 13, 2009

Time	Title	Speaker	Country
Plenary Lectures:			
08:25-08:55	Application of Robotics in Basic Rehabilitation Research	Prof. Dr. Volker Dietz	Switzerland
08:55-09:25	Modern Approaches to Stroke Rehabilitation → Abstract not available	Prof. Dr. Andreas R. Luft	Switzerland
09:25-09:55	Potentials of New Technologies in Clinical Practice	Prof. Dr. Jane Burridge	UK
10:15-10:45	Novel Methods for Restoration of Upper Limb and Hand Function	Dr. Silvestro Micera	Italy / Switzerland
10:45-11:15	The Neutral Bases of Movement Therapy - An Overview	Prof. Dr. Sten Grillner	Sweden
11:15-11:45	Engineering the Injured Spinal Cord	Prof. Dr. Martin E. Schwab	Switzerland
Parallel Session 1: New Technology in Rehabilitation			
14:50-15:20	Physiological Mobilization of Very Acute SCI Patients-Effects on the Cardiovascular System	Dr. Rüdiger Rupp	Germany
15:20-15:50	Therapy with Unconscious Patients on the Erigo Compared to Conventional Tilt Table; A Controlled Study and Future Development	Dr. Friedemann Müller	Germany
15:50-16:20	Robotics in the Rehabilitation of the Upper Limbs: First Experiences with Armor and Amadeo	Prof. Dr. Leopold Saltuari	Austria



Time:	Title	Speaker	Country
Parallel Session 2: Augmented Feedback			
14:50-15:20	Child Friendly Virtual Reality in Gait Training	Dr. Andreas Meyer-Heim	Switzerland
15:20-15:50	Augmented Feedback in Gait Rehabilitation with the Lokomat	Dr. Lars Lünenburger	Switzerland
15:50-16:20	Upper Extremity Rehabilitation Using Robotics and VR	Prof. Dr. Marko Munih	Slovenia
Parallel Session 1: New Technology in Rehabilitation			
16:40-17:10	Robotics-Assisted Treadmill Therapy Improves Walking and Standing Performance in Children and Adolescents with Cerebral Palsy	Dr. Ingo Borggraefe	Germany
17:10-17:40	New Technology in Neurorehabilitation – Achievements and Challenges → Abstract not available	Prof. Dr. Jürg Kesselring	Switzerland
17:40-18:10	Evidence-based Therapies for Upper Extremity Dysfunctions	Prof. Dr. Joachim Liepert	Germany
Parallel Session 2: Augmented Feedback			
16:40-17:10	Virtual Reality and Video Processing for Advanced Human-Computer Interaction → Abstract not available	Prof. Dr. Markus Gross	Switzerland
17:10-17:40	Robot-Assisted Rehabilitation of Hand Function with Adapted Sensorimotor and Psychological Feedbacks	Dr. Etienne Burdet	UK
17:40-18:10	The Effect of Assist-As-Needed in Robotic Gait Therapy: A Pilot Study	Dr. Herman van der Kooij	The Netherlands
Plenary Lectures:			
18:30-19:10	Re-Learning Motor Control using Virtual Environments	Dr. Maureen K. Holden	USA

Application of Robotics in Basic SCI Rehabilitation Research

Prof. Dr.V. Dietz and M. Bolliger

Spinal Cord Injury Centre, University Hospital Balgrist, Zurich, Switzerland

Locomotor activity and spinal reflexes show common features in different mammals, including humans. The application of robotics, such as the Lokomat to assist stepping movements, allows us to study these features in complete SCI subjects. Here we report the time course of the development of locomotor activity and spinal reflexes after a complete spinal cord injury (SCI) in humans. Spinal reflexes evoked by tibial nerve stimulation were studied, as was the leg muscle electromyography (EMG) activity evoked by mechanically assisted locomotion (Lokomat) in biceps femoris (BF), rectus femoris (RF), tibialis anterior (TA) and gastrocnemius medialis (GM) (Dietz 2002; Dietz and Müller 2004). A few months after the injury, an early reflex component (latency 60 – 120 ms) appeared, as in healthy subjects, whereas little leg muscle activity was present during assisted locomotion. At around 6 months after injury an additional, late, reflex component (latency 120 – 450 ms) appeared, which remained even 15 years after the SCI. In contrast, the early component had markedly decreased at 18 months after injury. These changes in spinal reflexes were associated with a loss of EMG activity and a successively stronger EMG exhaustion (i.e. decline of EMG amplitude) during a locomotor training session, when comparing the level of EMG activity at 2 and 10 min, respectively (figs 1 and 2). The loss and exhaustion of EMG activity during locomotion affected the BF, GM and TA but less the RF. When the amplitude-relationship of the early to the late reflex-component was calculated, there was a temporal relationship between the decrease of the early reflex and the increase of the late component and the degree of exhaustion of locomotor activity. Our data are consistent with a proposal of a common mechanism underlying the changes in spinal reflex activity and locomotor activity after SCI. These findings should be taken into consideration in the development of novel rehabilitation schemes and programs to facilitate regeneration-inducing therapies in SCI subjects.

This work was supported by the European Commission by the seventh framework programme through the project 'Spinal Cord Repair' (HEALTH-F2-2007-201144) and by the Swiss National Research Foundation (NCCR Neuro).

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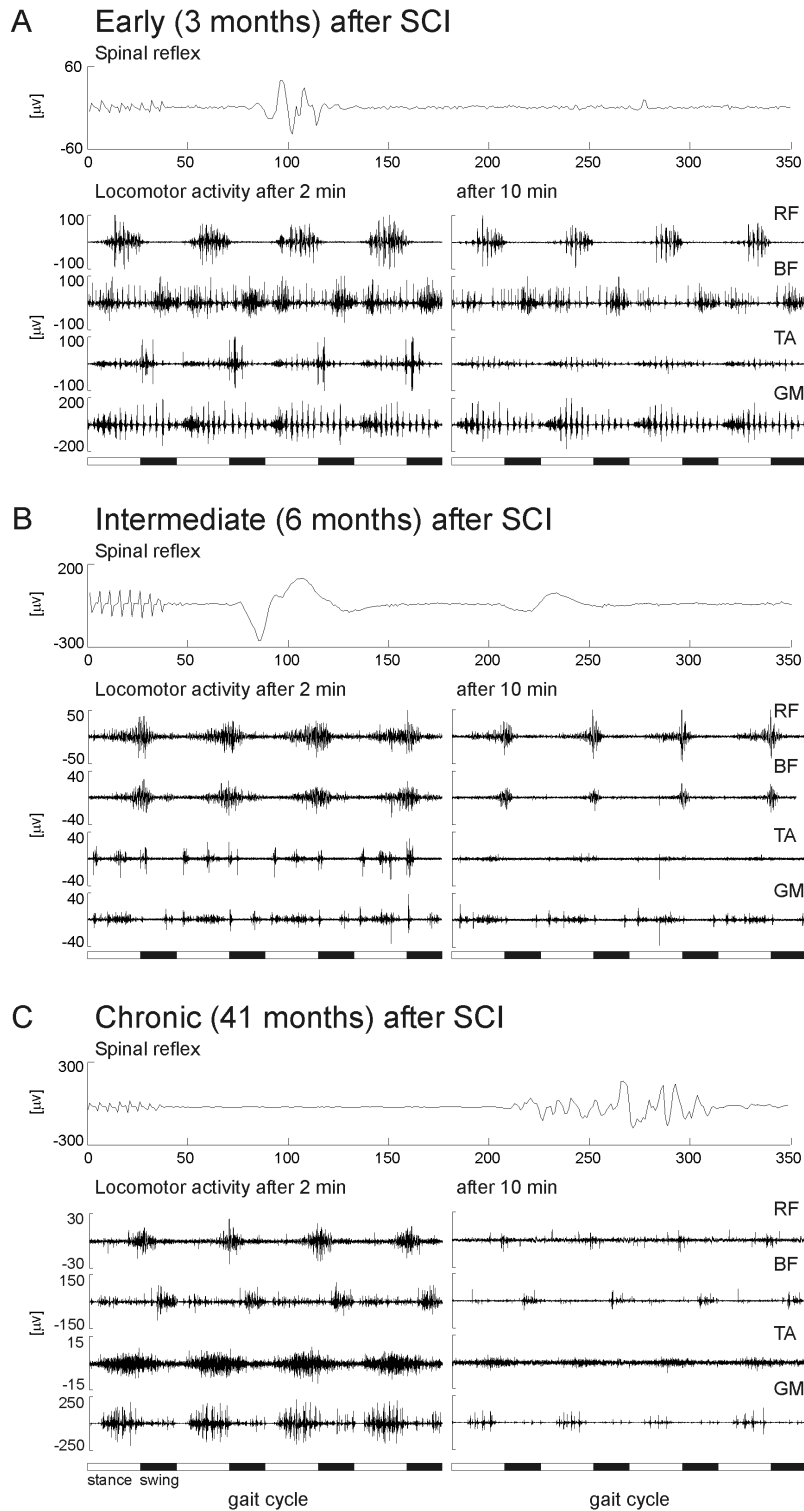


Fig.1: Spinal reflex and locomotor activity

The representative examples of the two components of spinal reflex (SR) and locomotor activity at early (A), intermediate (B) and late (C) stages after a complete SCI. The SR was evoked by tibial nerve stimulation (see methods) and recorded over the ipsilateral tibialis anterior muscle. The leg muscle activity is shown at the beginning (left side) and after 10 min (right side) of assisted locomotion.

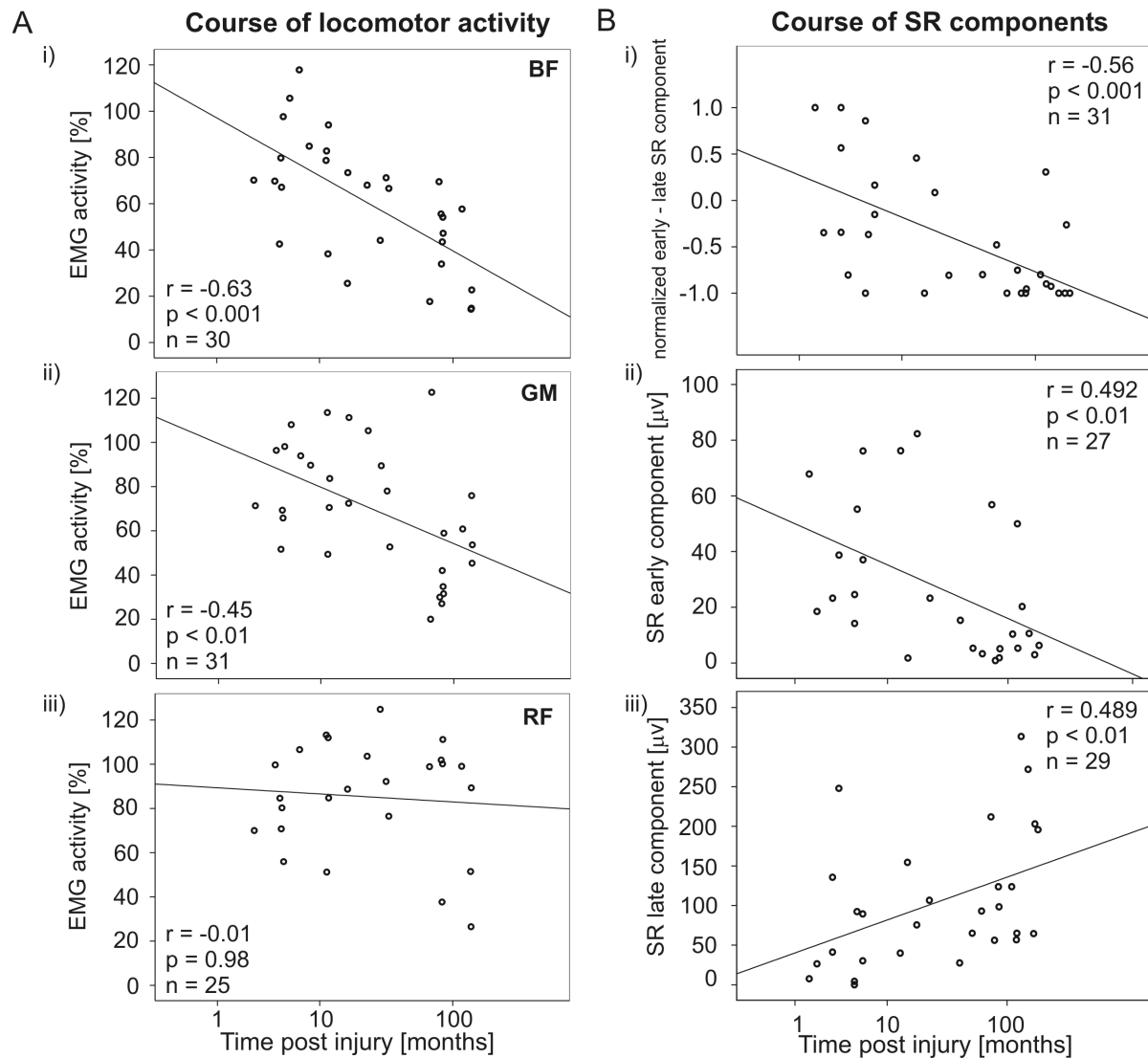


Fig. 2: Course of SR and leg muscle EMG

The change in BF (i), GM (ii) and RF (iii) EMG activity during 10 min of assisted locomotion (A) and the course of the two SR components (in the tibialis anterior) (B) is shown for all SCI subjects during the course after injury (for each graph 25-31 measurements). The changes in the SR components are presented as normalised ((i), early minus late component) and absolute ((ii) early and (iii) late component) values. The time after SCI is displayed on a logarithmic scale.

Potentials of New Technologies in Clinical Practice

Development, evaluation and application of new technologies need to take account of: societal and clinical needs; what is technically possible; the evidence to support their use from neuroscience; clinical effectiveness and users' perspective.

Prof. Dr. Jane Burridge, Professor Restorative Neuroscience
School of Health Sciences, University of Southampton UK

Societal drivers

Nearly 25 percent of people in the European Union in 2030 will be above age 65 (an increase of 17% from 2005). There is also an 80% chance that Europe's old-age dependency ratio (the number of people age 65 and older compared with the number of working-age people [ages 15-64]) will more than double by 2050, from one in four to fewer than one in two. [1]. If the capacity of health services is to meet future demand, we need to provide rehabilitation outside the hospital. Novel technologies, have the potential to not only reduce cost but also to add benefit by increasing intensity of therapy, improving motivation and by shifting the emphasis of responsibility for good health from healthcare professional to patient.

Technological opportunities

During the last decade a revolution in the use of technology in rehabilitation has begun and is gaining pace. Functional Electrical Stimulation; used in only a few specialist centres around the world of in the mid 1990s is now accepted clinical practice; over 6000 patients across the UK registered with the National Clinical FES centre in Salisbury UK and approval by NICE for the use of FES for foot-drop is imminent. In the US reimbursement has been approved for the Bioness L300 for SCI. Development of rehabilitation robots began more recently – the first clinical use of the MIT Manus was in 1991, but the number of devices and patients using them is increasing rapidly. New robot therapy systems are emerging that have the potential to be used in the home. These developments have been made possible by advances in electronic and software design, signal processing and control engineering and have been driven by a better understanding of the neuroscience of motor learning and control.

Clinical drivers

Historically Rehabilitation has been the poor relation in medical science. Most of what therapists did lacked any scientific rationale or evidence for effectiveness. One reason for this is the complexity of the conditions and the problem of designing clinical trials to assess an intervention that was dependent on the individual providing it; the double-blind randomised controlled trial is rarely applicable to evaluating rehabilitation interventions. Current research has however highlighted a few important points: that no one therapeutic approach seems to be more effective than any other [2] but that intensity is important [REF]. These two findings have paved the way for the introduction of technologies that can provide patient focused intensive exercise without increased demand on therapy time.

Neuroscience

Clinical findings have been supported by neuroscience and neuroscience has provided a better understanding of the process of motor learning and re-learning. Both have directed new rehabilitation approaches [4]. Studies with non-human primates that identified the phenomenon of learnt non-use of the hemiplegic forelimb, and the effect of constraining the non-affected limb on recovery [5], led to the development of Constraint Induced movement Therapy (CIMT). Studies of rats identified the effect of an enriched environment on motor recovery [6] and studies with intact squirrel monkeys showed that repetition of tasks was not enough and that functional cortical re-organisation was dependent on the task being 'challenging' [7]. Both supported the concept of rehabilitation robots and informed the development of partial Bodyweight Support Treadmill Training – and consequently devices such as the Lokomat.



Clinical Evidence

For rehabilitation technologies to be translated into clinical practice efficacy and practicality must be demonstrated. This is the now the focus of considerable research and runs in parallel with development of technologies. In some ways the process of clinical evaluation is in conflict with technical development. It takes at least three years to conduct a well powered clinical trial, by which time the technology will have progressed. It is tempting therefore to avoid such lengthy evaluation – but, this is the currency of healthcare providers and cannot be ignored.

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Novel Methods for Restoration of Upper Limb and Hand Function

Dr. Silvestro Micera, Assistant professor of BioRobotics
Scuola Superiore Sant'Anna, Pisa, Italy
Swiss Federal Institute of Technology, Zurich, Switzerland

Many research groups have shown that robot-mediated neuro-rehabilitation is effective in reducing motor impairments. Up to now, in most of the cases, the standard robotic therapy uses the device in order to move the subject's arm similarly to what a therapist does in hand-over-hand assistance during conventional therapy. As many other research groups have recently pointed out, there is no reason to believe that this is the only optimal treatment. On the contrary, robot-assisted therapy can be delivered in a variety of ways to reduce motor impairment and enhance functional motor outcomes. Improvements in the effectiveness of these therapies may be achieved by incorporating new approaches into the robotic-based exercises.

During this lecture, some innovative approaches will be presented: (i) the use of unstable training force fields to enhance path errors performed by the subjects; (ii) the EMG-based control of robots for upper limb function restoration (iii) the combined use of robotics and functional electrical stimulation to restore reach-to-grasp tasks.

The lecture will outline the scientific bases of these methods, analyze the main techniques that can be exploited to implement them, present the solutions that have been explored so far, and discuss the perspectives of these new approaches in the near and long term future.



The Neural Bases of Movement Therapy – An Overview

Prof. Dr. Sten Grillner

Nobel Institute for Neurophysiology, Dept. of Neuroscience, Karolinska Institutet Stockholm, Sweden

Locomotor movements require an effective propulsion, control of body orientation, a goal-directed element and accurate foot placement. These different aspects are controlled by separate, but well integrated neural control systems. In this lecture the focus will be on the neural generation of the propulsive movements. I will review the general features of the overall control system – forebrain – brainstem – spinal cord – movement related sensory feedback. I will use examples from different experimental models, ranging from humans to lower vertebrates. The networks producing locomotor behaviour are comprised of glutamatergic and glycinergic neurons in the spinal cord, which are activated by reticulospinal neurons. In addition to the intrinsic spinal locomotor networks – there is a set of sensory control systems that help regulate and adapt the activity of the central networks. They are subject to activity dependent plasticity – in an important aspect accounting for the effects of movement therapy. The generation of the motor pattern, with accurate timing of the different locomotor bursts, is dependent not only on the connectivity but also on the membrane calcium-dependent potassium channels, different subclasses of calcium channels and NMDA – receptor induced plateau properties. The different ion channels are also the target of different modulators which can modify cell properties as well as presynaptically change the gain of synaptic transmission. The cellular mechanisms that appear important in producing an accurate and well-controlled motor output will be discussed.

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Engineering the Injured Spinal Cord

Martin E. Schwab
Brain Research Institute
University of Zurich / ETH Zurich

Interrupted fibre tracts in the injured spinal cord do not spontaneously re-grow. They show, however, formation of sprouts at the proximal axon stump (regenerative sprouting, often transitory) and along the proximal axon. These sprouts can contact neurons in the upper part of the spinal cord. Experiments in adult rats with thoracic spinal cord lesions have shown that transected corticospinal hind limb fibres sprout into the cervical spinal cord; stimulations of the former hind limb motor cortex in these animals can evoke fore limb movements suggesting the formation of new forelimb circuits from former hind limb areas. Interestingly, imaging of fore limb sensory connections show that short latency responses can be recorded from the hind limb sensory motor cortex upon fore paw stimulation 7 days to 12 weeks after injury, suggesting that the sensory input adapts to the rewiring of the motor output in response to the spinal cord injury.

Cell and molecular biological studies have shown that specific growth-inhibitory factors are present in the adult spinal cord and brain; these factors are crucial players for the restriction of long distance regeneration and compensatory fibre growth following CNS injury. A very potent growth-inhibitory factor is Nogo-A, a membrane protein enriched in CNS myelin. Its neutralisation by function-blocking antibodies infused into the CSF lead to long distance regeneration of transected spinal fibre tracts, enhanced compensatory fibre growth from spared fibres, and significant enhancement of recovery of lost sensory motor functions in rats and non-human primates. The almost complete recovery of skilled hand movements in spinal cord injured adult Macaque monkeys demonstrates a high degree of specificity of these experimentally-induced repair processes. In collaboration with Novartis and an international network of paraplegia clinics (EUCTN, NACTN), a clinical trial is currently ongoing, where paraplegic patients are infused with a human anti-human-Nogo-A antibody intrathecally within two weeks after the accident.

Physiological Mobilization of Very Acute SCI Patients Effects on the Cardiovascular System

Rüdiger Rupp, Harry Plewa, Christian Schuld, Michael Schmidt, Hans Jürgen Gerner
Orthopaedic University Hospital, Heidelberg, Germany

Introduction

In addition to sensory and motor deficits, individuals with spinal cord injury (SCI) are prone to autonomic disorders. Orthostatic hypotension (OH) can cause symptoms of presyncope including dizziness, and nausea, and may lead to neurogenic syncope especially in the acute phase after SCI [1]. As such, OH hinders early rehabilitation of SCI patients and leads to a delayed onset of physio- or occupational therapy [2]. However, the overall time available for primary rehabilitation decreases rapidly, thus rehabilitation needs to begin as early as possible in order to be effective.

Tilting and FES (Functional electrical stimulation) assisted cycling are the state of the art, clinically established therapeutical options for prevention of OH. However, up to now no concept has been established for combined verticalisation and physiological movement of the legs.

Patients and Methods

The Erigo device (Hocoma AG, Volketswil, Switzerland) is based on a tilt table for verticalisation and generates an almost normal gait pattern with physiological loading of the legs (Fig. 1) [3].

We included 5 patients (\bar{x} 33.0, range 19 to 45y) with a traumatic, clinically complete (ASIA Impairment Scale A) SCI in a study to confirm, that a circulatory stabilisation and training of complete high-lesioned SCI patients is possible with the Erigo device. The onset of inclusion in the study was 56.8 days (range 33 to 98 days) after injury. The neurological level of lesion was between C4 and C7. Voluntary muscle function in the lower extremities was completely absent in all patients.

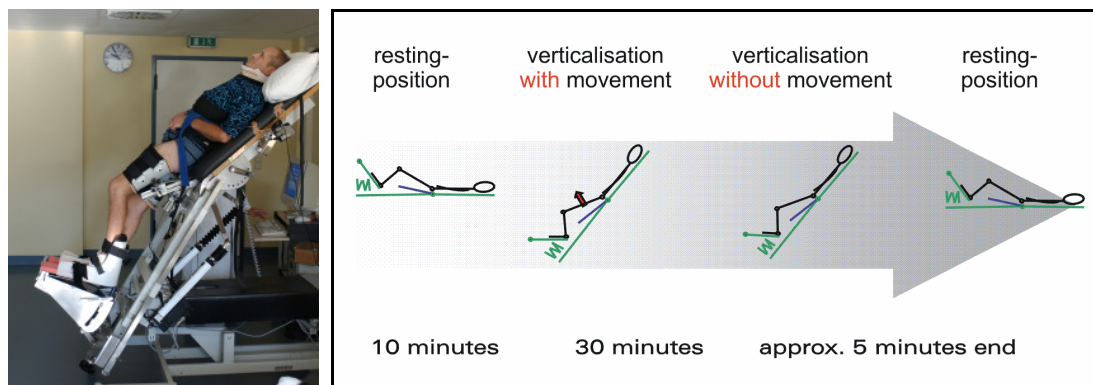


Fig. 1: Application of the Erigo prototype and overview of the therapy protocol.

We carried out an Erigo training over 3 weeks. The training sessions were divided in three phases: First, the patients lied in a resting position (baseline), in the second phase (therapy) the legs were mobilized and the tilt was adjusted to 60° upright position, whereas in the last phase (evaluation) patients were kept in the upright position with the movement halted (Fig. 1). During all phases RR, pulse, ECG and clinical parameters were assessed every 5 min.

Results

No symptoms of pre-/syncope have occurred during therapy. The mean arterial peripheral blood pressure (MAP) was stable during the 30-minutes therapy interval. However, the MAP decreased significantly ($p < 0.001$) at the end of the verticalisation phase, as soon as the leg movements were stopped (Fig.2). Over the 3 weeks therapy course there seems to be a trend (not significant) towards a better adaptation (higher blood pressure with lower pulse frequency) to orthostatic stress (Fig. 2).

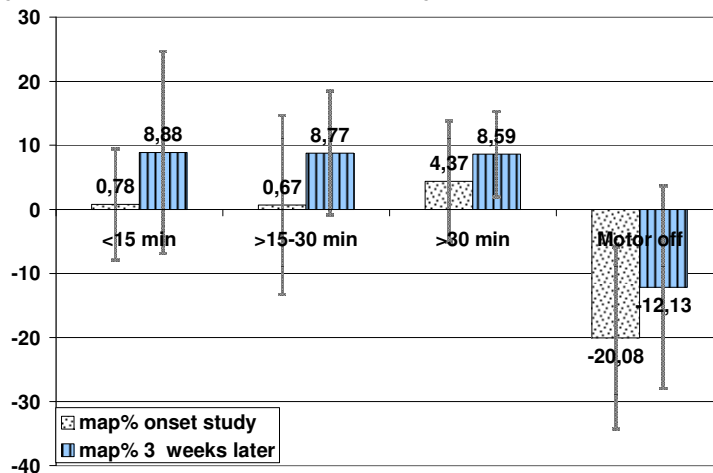


Fig. 2: Normalised mean arterial pressure (% baseline) during therapy intervals “0-15 minutes” (average of 0, 5, 10 min recordings), “15-30 minutes” (average of 15, 20, 25 min recordings), “30 minutes” and after stopping of the movement still with fixed head-up tilt.

Discussion and conclusion

From our results we conclude, that Erigo therapy is applicable in the earliest rehabilitation of SCI patients and is effective in the therapy of orthostatic hypotension. During the physiological, passive stepping movements an increased cardiac activity occurred, which may result in better cardiac fitness.

In a recent study we found a load dependent effect on the electromyographic (EMG) activity of the leg muscles. However, since the overall low EMG activities do not explain the presented results in terms of sufficient activation of the muscle pump we assume that an activation of the sympathetic nervous system triggered by afferent stimuli occurs via spinal crosslinks.

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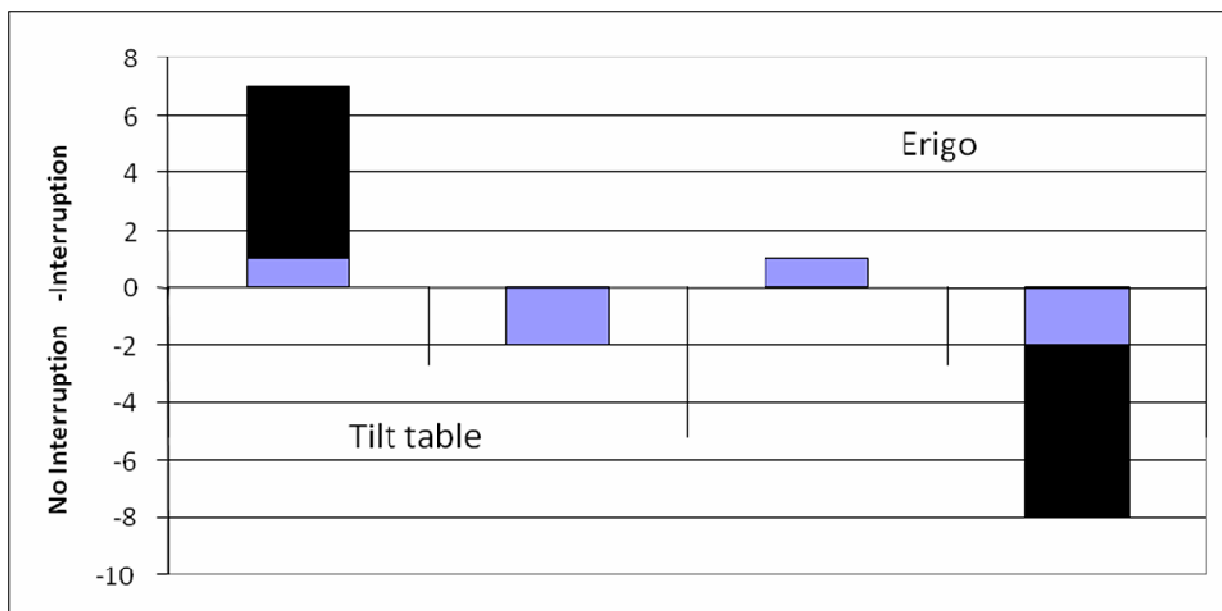
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Therapy with Unconscious Patients on the Erigo Compared to Conventional Tilt Table. A Controlled Study and Future Development

Dr. Friedemann Müller, Head Physician Neurology
Neurological Clinic Bad Aibling, Germany

Technological advancements in neurorehabilitation have led to increasing use of technical support. Some of the most valued technological developments either reduce fatiguing tasks or enable highly repetitive exercises. Thus, they enable therapists to perform procedures that would otherwise have been difficult or impossible to accomplish. Electromechanical systems combined with electronic control setups are increasingly better suited to the rehabilitation of severely affected patients. Exercises become easily performed, that used to be both physically demanding for care providers and – with standard instrumentation – minimally productive for patients.

Mobilization is probably the major goal in the management of patients recovering from severe neurological disorders, like traumatic brain injury and cerebrovascular accident. One of the new systems, the so-called Erigo with potential to accelerate early rehabilitation of patients combines a tilt table with a computer controlled stepping mechanism. Experience at our institution suggests this system may alter the way in which patients are treated in intensive care units, as well as enhance early and intensive rehabilitation protocols that ideally begin as soon as the patient is stabilized. Data are presented that show how the combination of these two technical principals enables those patients to be put into the vertical position who repeatedly suffered from orthostatic hypotension after a severe traumatic brain injury. In a controlled study with 9 unconscious patients we compared in each patient a mobilization with a regular tilt table with mobilization in the advanced table with integrated stepping. Tendencies to syncopes can almost completely be controlled by simultaneous stepping. This is of tremendous importance as it can help to avoid bed-rest deconditioning. In addition, therapists assume that even the duration of unconsciousness might be shortened if the patient could be raised to some degree of vertical position.



$p < 0.05$

The figure demonstrates the 18 trials of verticalization and shows significantly less interruptions on the Erigo.



Recent data from the group of Prof. Milos Popovic in Toronto indicate an enhanced effect of simultaneous functional electrical stimulation while stepping. We report first experiences when using the combination of a tilt stepper with stimulation of the leg muscles in severely disabled patients. Due to a newly developed interface this technique can be easily applied by a therapist.

In summary exoskeletal orthoses enable severely impaired patients to exercise movements and assume positions that would be difficult to obtain otherwise. While immediate positive effects are obvious, there is also a hope, that long-term effects can be proven that augment neurorehabilitative efficacy.

Robotics in the Rehabilitation of the Upper Limb: First Experiences with Armor and Amadeo

Prof. Dr. Leopold Saltuari, Head of Neurology and Andreas Mayr, Human Movement Scientist
Rehabilitation Clinic Hochzirl, Austria

Objectives

Functional improvement of the upper limb after stroke continues to be a challenge for therapists in neurorehabilitation. Considering the complex symptoms of the upper motor neuron syndrome, robot-assisted training seems to provide valuable enhancement of therapeutic strategies to improve control of the paretic arm and hand. Intensive therapy and task-oriented training has been shown to be useful in rehabilitation of the lower limb. The development of two new electromechanical devices for the upper limb may also help to improve function after stroke.

Methods

The Armor system functions as an exoskeleton, and consists of two electromechanical orthoses; a passive device which measures the trajectories of the upper limb, and an active device which moves the patient's paretic limb. An integrated trunk support stabilizes the patient while seated to ensure safe training. Eight servomotors move the entire upper limb from the shoulder to the MCP joints of fingers and thumb. Varying control mechanisms allow for individual implementation of the movement.

The Amadeo system is an end-effector-based system which moves the patient's fingers in a closed movement chain. After the patient's fingers are fixed magnetically to the fingerslides, the device allows each individual finger and the thumb to move independently and separately on a predefined path.

Range and force of both systems can be adjusted according to the patient's impairment. Resistance measurements were conducted with three different speeds (Armor: $v=10^\circ/s$, $40^\circ/s$, $80^\circ/s$; Amadeo: $v=2$ mm/s, 20 mm/s, 40 mm/s) and strength was tested in flexion and extension against a preset resistance of the system and with electrical stimulation respectively. The Action Research Arm Test was used to interpret functional improvement.

Results

Preliminary results of the Armor training showed significant reduction of pathological muscle tone and non-significant improvement in dexterity. The automatized training led to better improvement in early than in later phases, and positively influenced recovery.

During testing with the Amadeo, normal subjects and patients with flaccid hemiparesis showed little or no resistance in all fingers, with no difference between various speeds. The patients with spastic muscle tone showed not only higher resistance than the healthy subjects, but also differed strongly with diverse movement speeds; interestingly enough, the highest speed produced the least resistance. Strength measurements exhibited higher values for finger flexion than for finger extension.

Conclusion

These novel electromechanical devices measure important clinical features of stroke patients, and therefore could objectify the patient's progress during rehabilitation. The efficacy of the two different training concepts in both systems – closed or open chain - in enhancing functional recovery of patients with central lesions must be proven. Furthermore, both systems appear to be adequate devices for more intensive and extended training sessions, allowing for precise repetition of limb and finger movements.

Child Friendly Virtual Reality in Gait Training Robotic Assisted Gait training in a Child Friendly Virtual Environment

Dr. Andreas Meyer-Heim

Rehabilitation centre Affoltern am Albis, University Children's Hospital Zurich, Switzerland

Robotic assisted gait therapy offers nearly optimal conditions for intensive gait training as several requirements of modern principles of sensorimotor learning, such as task specificity and repetition with variation, have been achieved by this method. The Pediatric Lokomat has been proven to be a feasible treatment option in children with central gait impairment. Level III studies have shown some evidence of effectiveness with functional and qualitative improvement of gait parameters. However, body weight supported automated treadmill training can still be a tedious and, especially for children and young patients, a sometimes boring process. The aim of our research effort is to improve patient's motivation and active participation during gait training in order to enhance the motor learning process and neuroplasticity.

In close cooperation with the Sensory Motor Systems Laboratory (ETH), Hocoma and the Zurich University of Arts (ZHdK), child friendly game scenarios in a virtual reality environment have been developed and are being steadily improved. In addition to the game character, which enables interactive immersion into a game, safety and reliability are the challenging requirements of such gaming scenarios. A present version consists of a soccer game allowing children to kick a ball and to compete with an opponent. Preliminary data from EMG studies and from the Lokomat biofeedback evaluation tool (L-Walk) of children walking in various and randomised conditions show a significant increase in activity of muscles measured and in the motor output respectively. Many open questions need to be investigated in future research and will be discussed at the INRS.



Fig. 1 Soccer scenario (PeLoViR) including avatar, two opponents and a ball

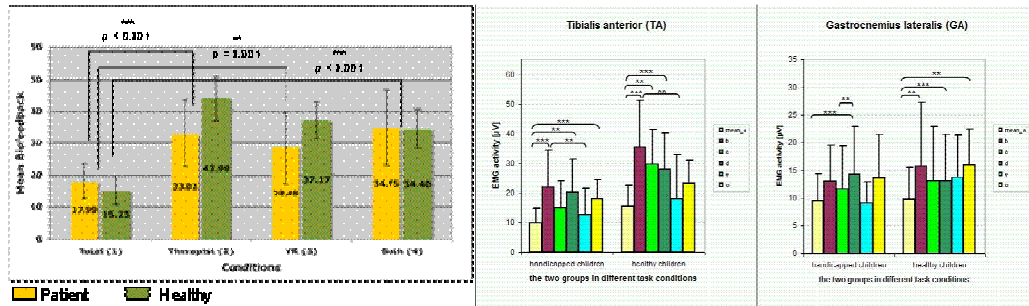


Fig. 2 a & b: Biofeedback (L-walk) data (a) and EMG data (b) of patients with cerebral palsy and healthy children showing muscle activity in different conditions (2 min) of engagements.

Conditions in Fig 2 b: (a) walking active on Lokomat, (b) motivated by therapist, (c) motivated by VR (soccer), (d) motivated by both VR and therapist, (e) augmented feedback, (o) walking on treadmill (without BWS).

Augmented Feedback in Gait Rehabilitation with the Lokomat

Dr. Lars Lünenburger
Hocoma AG, Volketswil, Switzerland

Feedback is one important factor for successful motor training. Apart from allowing the correction of errors during the movements, the visibility of success and improvement over time can be strong motivational factors. For movements of unimpaired individuals, feedback is often derived from afferents and re-afference such as proprioceptive, tactile or visual sensory inputs. In contrast to this intrinsic feedback, which results from the individual's perception of the movement (proprioception or vision of the moving limb, but also possibly the sound of the footsteps), extrinsic or augmented feedback may be provided additionally by an outside source, such as a therapist or coach. Extrinsic feedback is considered important for patients with neurological injuries, especially if the somatosensory pathways are affected. In robot-assisted rehabilitation, the robot itself can be used to generate and display the feedback.

In order to provide computerized extrinsic feedback with a rehabilitation robot, the patient's movement has to be quantified such that the resulting values can be displayed. Although these two steps can be regarded separately, they have to be coordinated in order to create a useful feedback. I will present several examples of feedback calculation and displays for the driven gait orthosis Lokomat® (Colombo et al. 2000; Hocoma AG, Volketswil, CH). An early approach used only simple line graphs on a flat screen display (Lünenburger et al. 2004). Despite the simplistic display the patients responded in favour of the motivating effect (average 2.2 on a scale of 0 to 3) and requesting this feedback for their next training (average 2.6). The underlying values were calculated as weighted averages of the torques registered by the Lokomat drives. Systematic evaluation with a larger group of patients (Banz et al. 2008) showed that the computerized visual feedback is a valuable adjunct to robotic-assisted gait training. Subsequent developments lead to the application of virtual reality technology (e.g. the MIMICS project) on the display side and new quantification methods on the calculation side. Preliminary results show that patients and therapists respond positively also to this new augmented feedback system.

I will conclude that augmented feedback that is provided to the patients by the rehabilitation robots will be an important asset for this form of rehabilitation. Future developments should focus both on the assessment and the display. Additionally, experimental studies will have to extend our understanding of the requirements and prove the clinical efficacy of augmented feedback.

Acknowledgements

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 215756 and the Swiss Commission for Technology and Innovation projects 6199.1-MTS and 7497.1 LSPP-LS.

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Upper Extremity Rehabilitation Using Robotics and VR

Prof. Dr. Marko Munih

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Rehabilitation robots are starting to be important tool in clinical rehabilitation of stroke. They offer an automated training, a number of the training sessions with limitless duration, also a better guidance of the human arm, and among others as well activities of daily living (ADL) training with task-oriented movements.

Training session should be beneficial in terms of user increased short or long term functionality, and should be, maybe at first instance, also enjoyable. The human physiotherapist is applying tactile, verbal and visual stimuli for achieving mentioned goals. Thus, the current, predominantly robot movement therapy could be further improved through better immersive and complete multimodal sensory feedback. Our approach is real-time acquisition of behavioral and physiological data from patients and use of this to adaptively and dynamically change the displays of an immersive virtual reality system, haptic environment or response with rehabilitation robot, as well as use of auditory stimuli with the goal of maximizing patient motivation. Such complex system should be natural, user-friendly and easy to use.

The system for rehabilitation of upper extremities is exploiting an end-effector approach, the haptic robot is HapticMaster from FCS. At the tip is attached a 2R passive gumball and our passive 1DOF grasping device with adjustable stiffness. Gravity compensation system is an active system, separately for upper and lower arm. 3D projection system consists of two projectors, a back projection screen and a multimedia computer. The sound surround system of 5.1 system configuration has three speakers in front, two speakers behind the subject and a subwoofer. Biosignal recording equipment includes biosignal amplifier, skin conductance sensor, respiratory rate sensor, skin temperature sensor electromyography electrodes and biosignal dedicated computer.

In first tests a smaller Phantom robot was used in order to minimize physical activity. The psychophysiological responses to different tasks were viewed in the light of the arousal-valence model, which describes a person's mental state with two variables: arousal (general level of mental activity) and valence (the type of emotions, from very positive to very negative). Additionally, the subjects' mental states were estimated using questionnaires. Heart rate, heart rate variability (HRV), skin conductance level, skin conductance responses (SCR), respiratory rate and skin temperature were recorded and compared both between subjects and between tasks. Skin conductance was found to be mainly influenced by arousal, heart rate, HRV and skin temperature were more closely connected to valence, though the results also suggested some effect of arousal (Figure 1).

In a second study, using HapticMaster, larger movements and thus more physical effort, we were able to demonstrate a significant influence of both mental arousal and emotional valence on physiological responses even in the presence of significant physical load.

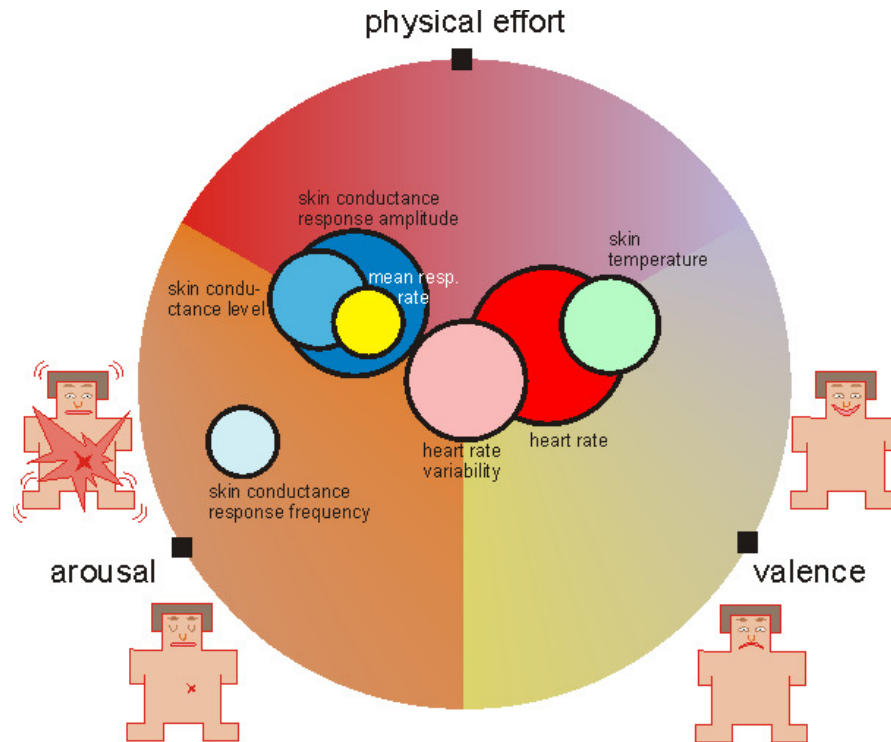


Figure 1 The distance of a circle's centre from each of the three black squares represents the effect that square has on it; the shorter the distance, the greater the effect.

The radius of an inner circle represents variability between subjects; a larger radius means that physiological responses vary more strongly between individuals.

Please note that this sketch represents only a general summary of our assessments and would require further measurements with different environments and stimuli to be perfectly accurate.

Acknowledgement

The work was funded by the EU Information and Communication Technologies Collaborative FP7 Project MIMICS, grant 215756.

Robotic-assisted Treadmill Therapy Improves Walking and Standing Performance in Children and Adolescents with Cerebral Palsy

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Introduction

Task-specific body-weight-supported treadmill therapy improves walking performance in children and adults with central impairment. The aim of the study was to investigate the effect of robotic-assisted treadmill therapy regarding on standing and walking performance in children and adolescents with cerebral palsy. In addition, predictors for outcome were evaluated and adverse events were documented.

Methods

20 patients (mean age 11.0±5.1, 10 males and 10 females) with cerebral palsy underwent a trial consisting of 12 sessions of robotic-assisted treadmill therapy using the commercially available driven gait orthosis Lokomat. Outcome Measures were the dimensions D (standing) and E (walking) of the Gross Motor Function Measure (GMFM). In addition, safety parameters were evaluated in a cohort of 41 children with central gait impairment using a standardized questionnaire.

Results

Significant improvement in dimension D by 5.9% (± 5.2, p=0.001) and dimension E by 5.3% (±5.6, p<0.001) of the GMFM were achieved. Improvements in the GMFM D and E were significantly greater in the mildly affected cohort (GMFCS I and II) compared to the more severely affected group (GMFCS III and IV, p<0.005). Improvement of the dimension E but not of D correlated positively with the total distance walked during the trial (rs=0.748, p<0.001). No serious adverse events were documented. 2 out of 41 patients had to discontinue the therapy sessions due to open skin lesions or tendovaginitis.

Conclusions

Children and adolescents with bilateral spastic cerebral palsy showed improvements in the functional tasks of standing and walking after a trial of robotic-assisted treadmill therapy. The severity of motor impairment affects the amount of the achieved improvement.

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Evidence Based Therapies for Upper Extremity Dysfunction

Prof. Dr. Joachim Liepert, Head Physician Neurorehabilitation
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Within the last two decades, research in neurorehabilitation has grown considerably. Numerous randomized controlled trials help to decide which treatment is effective or even superior to another one. This presentation reviews the current knowledge about evidence based therapies for upper extremities.

Most studies dealing with the treatment of upper extremities have been performed in stroke patients. Therefore, evidence based knowledge is limited to this patient group.

Increasing the intensity of rehabilitation leads to a faster and stronger improvement of motor functions. Treatment duration should be increased by at least 2 hours per week and should include elements of task orientation and activity orientation. Constraint induced movement therapy (or forced use therapy) produces a significant and persistent improvement of motor functions in patients suitable for this therapy. Patients should be able to extend the fingers by at least 10 degrees and the wrist by at least 20 degrees prior to initiation of therapy. Bilateral arm training should be considered in patients with a more severe paresis.

There is some evidence that a treatment specifically aimed at the severity of motor impairment ("Impairment oriented training") leads to stronger restitution of functions than a less specific training. This has been shown for patients with moderate impairment (Arm Ability Training) and for severely affected patients (Arm Basic Training).

Patients with a severe paresis may also benefit from electrical stimulations. EMG triggered electrical stimulation of forearm extensors improved the strength of wrist extensors but was not effective in improving activities of daily living. Functional electrical stimulations include the use of several electrodes, allowing for example to train to grasp and release an object. There is limited evidence that FES is effective.

Most studies addressing Arm Robot therapy have been performed by the investigator group that had developed the MIT Manus. Results indicate an improvement of upper arm functions that persists over years. However, results should be replicated by other groups.

Another interesting treatment uses a mirror. When looking in the mirror and moving the unaffected arm, the patient develops the impression that he is able to move his affected arm. Results are promising but should be demonstrated in larger patient groups.

Motor imagery or mental training has for long been used in sports and is now increasingly applied in stroke patients. Current results suggest that it is effective but some aspects as the question whether the lesion location (left or right hemisphere) determines the ability to imagine movements still need to be clarified.

New technologies include brain stimulations with repetitive transcranial magnetic stimulation or with transcranial direct current stimulation, but it is too early to come to final conclusions. Another promising new approach is the combination of virtual reality and upper extremity exercises since this treatment combines cognitive aspects with repetitive motor training.

Robot-Assisted Rehabilitation of Hand Function with Adapted Sensorimotor and Psychological Feedbacks

Dr. Etienne Burdet, Senior Lecturer
Department of Bioengineering, Imperial College London UK

Stroke often impairs the hand function, which critically affects patients in their activities of daily living such as eating, objects manipulation or writing. This talk will describe our interactive approach to robot-assisted rehabilitation of hand function. We designed a compact and flexible robotic system, and developed exercises training specific hand functions, and providing suitable sensorimotor and psychological feedbacks to the subjects. These therapeutic games adapt the difficulty to challenge the subject and consider the current level of impairment. This talk will present this system and its successful use in a study with 12 chronic stroke patients at Tan Tock Seng Hospital in Singapore.



Biosketch

Dr. Etienne Burdet (<http://www.bg.ic.ac.uk/staff/burdet/Home.html>) is Senior Lecturer at Imperial College London and a Senior Research Fellow at the National University of Singapore. His group uses an approach integrating neuroscience and robotics to: i) investigate human motor control and ii) design efficient assistive devices and virtual reality based training for rehabilitation and surgery. This approach has generated significant achievements, including:

- The first clear evidence of how humans use impedance learning to control movements in unstable situations (Nature 414: 446-9).
- The first model of motor adaptation able to predict the whole evolution of muscle activation in novel stable or unstable dynamics (J of Neuroscience 28(44): 11165-73, 2008).
- Robotic devices for decentralized rehabilitation of hand function in home and rehabilitation centers (best paper award at IROS06).
- The first fMRI-compatible haptic interfaces, which are used in five labs in Japan and Europe to investigate the neural mechanisms of rehabilitation.
- A low-cost robotic wheelchair system which significantly reduces the effort necessary to control the wheelchair for cerebral palsy and traumatic brain injury individuals.

The Effect of Assist-As-Needed in Robotic Gait Therapy: A Pilot Study

Dr. Herman van der Kooij, Associate Professor Biomechanics,
University of Twente and Delft University of Technology
Enschede, The Netherlands

Introduction

Robotic support during gait training is a promising new field in the rehabilitation of stroke survivors. Encouraging stroke survivors to actively participate in robot aided gait training is crucial for optimizing functional recovery. Providing robotic support is necessary to assist the patient in performing gait tasks but, at the same time, the patient may decrease his own effort/contribution to the movement when he experiences support, and might become reliant on the assistance [1]. The aim of this pilot study was twofold. First, to assess the need for adaptive assistance and second, to assess the potential of adaptive assistance to trigger the patients' own initiative

Methods

LOPES is an exoskeleton type robotic gait trainer [2] and is impedance controlled and therefore suitable for adaptive assistance (variable stiffness). LOPES was used to selectively support the foot clearance of the affected leg of one male chronic stroke patient [3]. After a familiarization period, the patient first walked without assistance. Subsequently the robotic support of the foot clearance of the affected leg was switched on for a duration of 100 s, after which the support was turned off again. In a second trial, an attempt was made to trigger the patients' own initiative. Here, the level of support was changed on a step by step basis by systematically reducing the support ("forgetting factor"), preventing reliance, and adapting the support to the performance of the patient based on an error based learning law. With the adaptive support algorithm (adopted and modified from [1]) it is possible to relate the amount of support to the capabilities of the patient. After ± 20 steps the stiffness profile reaches a steady state where the forgetting factor and the deviation of the ankle from the reference pattern are in equilibrium (figure 1). Figure 2 shows that a constant level of support lifts the ankle more towards the reference value. However, when compared to adaptive support, constant support also causes the ankle height to drop more when the support is switched off.

Discussion

The sudden drop in maximum ankle height, when the support is switched off, provides support for the notion that patients can take advantage of prolonged support and may contribute little to the supported movement. Here, the patient allows the robot to take over most of the required "physical effort" to perform the additional movement. During adaptive assistance the drop in maximum ankle height is smaller which indicates that the patient contributes more to the required movement. Thus, to prevent the patient from becoming reliant on the supportive forces, the support should be decreased systematically. However, there is a limit, as stroke survivors also need this support in order to maintain a constant performance level. At the time of the symposium a first series of clinical trials will have been evaluated that will show the effect of haptic support and feedback to the patients using the AAN approach on patient's walking. Results will be compared with the results of walking in LOPES without any haptic support and feedback. In addition we will present a novel idea for the integration of visual feedback and haptic feedback and support in robotic gait training.

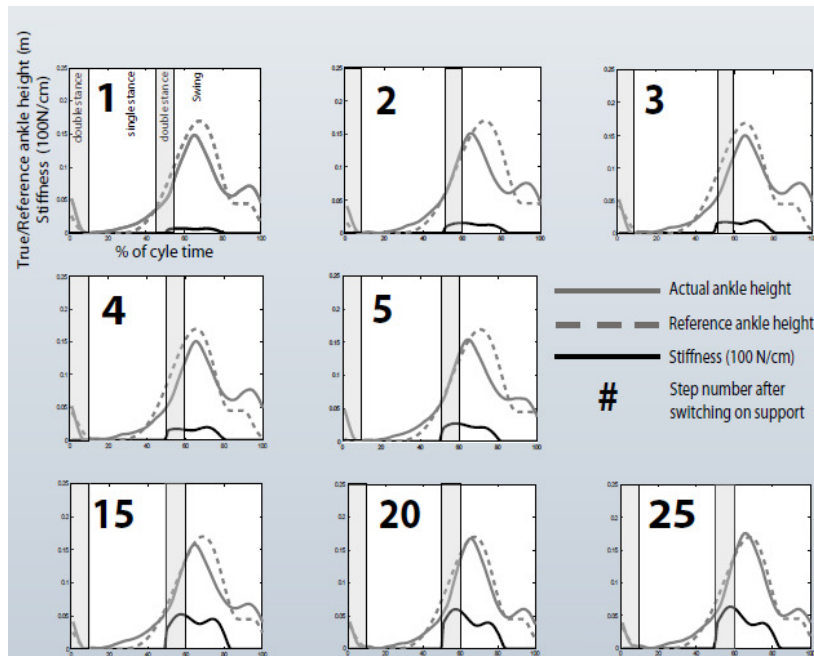


Figure 1: Actual ankle height (solid gray), reference ankle height (dashed gray) and adaptive stiffness (black) as a function of the amount of steps after which the adaptive support is switched on. Support is only applied during the double stance (with the paretic leg behind) and the paretic swing phase. The stiffness is cut off at zero since only supportive forces are desired.

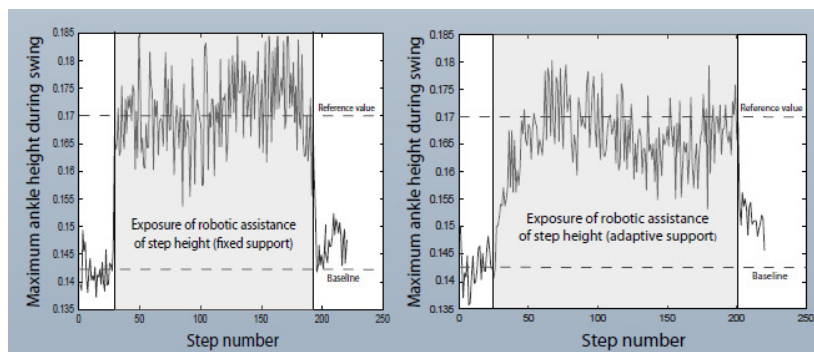


Figure 2: Maximum ankle height during the swing phase as a function of the step number. The left graph shows the step height when a fixed amount of support ($K=800\text{N/m}$) is provided. The right graph shows the step height during a trial where the amount of support is adapted on a step by step basis.



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Re-Learning Motor Control Using Virtual Environments

Maureen K. Holden, PhD, PT
Northeastern University, Boston, MA, USA

About ten years ago I published the first paper describing the use a virtual-environment-based (VE) system to aid motor relearning in patients with stroke. The intervening years have seen an exponential growth in this area of inquiry, not only in studies using VE as a method of treatment for motor relearning, but also in the development and use of robotic technology for this purpose. More recently, investigators have begun to combine robotics and VE technology in their therapeutic systems.

While a great deal of work has been accomplished in this past decade, the focus has been mainly on development of VE and robotic systems to assist rehabilitation, and to a lesser extent on studies which examine effectiveness of these systems in a rigorous fashion. As this field begins to mature, I believe the research focus should shift in the latter direction. What is needed is a better 'marriage' of motor learning principles and effective therapeutic exercise regimes with these new technologies. In turn, the knowledge gained from such inquiries can be used to drive the future development of the technology in a more effective way.

In this talk I would like to address a series of questions that can help to frame future study designs in the VE/ robotics arena. To illustrate these questions, I will describe results from studies in my laboratory on patients with neurological impairments such as stroke and traumatic brain injury, and relate these results to the issues I have raised for discussion. The questions/ issues I would like to discuss include the following:

- 1) What are the 'active ingredients' in motor re-learning? What role does VE technology play in re-learning – i.e., are technologies themselves a treatment or more an adjunct to treatment?;
- 2) How can we tell whether motor learning has occurred? What measures should be used to assess effectiveness of VE/robotic therapy?
- 3) How do factors such as practice schedules, conditions of practice and feedback type affect motor relearning in and out of VE?
- 4) How similar is VE to real world practice and how important is the veracity of the simulation to learning?;
- 5) How does the nature of the task to be accomplished drive the relevance of sensory inputs?
- 6) Do the advantages of VE systems for motor retraining translate to better results in terms of motor relearning when compared to other rehabilitation techniques?
- 7) Should future technological development move more toward expensive systems that can do a lot and are highly flexible in adapting to the needs of a wide variety of patients, or more toward inexpensive systems that do less but are easy to operate and can be used independently by patients in the home environment?
- 8) How easily can any of these technologies be used in a telemedicine framework?

I will conclude with a brief description of the future direction of my research in the areas of retraining complex hand functions and development of the NU ankle for lower extremity rehabilitation.



List of Posters

- 1.1 Temporal and Spatial Patterns of Cortical Activation during Lower Limb Movement.**
M. Wieser, J. Haefeli, L. Büttler, L. Jäncke, R. Riener and S. Köneke
Sensory-Motor Systems Lab, IRIS, ETH Zurich & SCI Center, University Hospital Balgrist, University of Zurich, Switzerland; Institute of Human Movement Sciences and Sport, ETH Zurich, Switzerland; HUMAINE Clinic Zihlschlacht, Switzerland; Institute of Psychology, Division Neuropsychology, University of Zurich, Switzerland
- 1.2 Active tilting a patient to erect position within a very early period of neurorehabilitation - cardiovascular stimulation.**
M. Łukowicz, W. Kuczma, J. Hoffman
Departement of Lasertherapy and Physiotherapy, Collegium Medicum, University of Nicolaus Copernicus Torun, Poland; Departement of Rehabilitation, Collegium Medicum, University of Nicolaus Copernicus Torun, Poland
- 1.3 Central and cerebral blood flow estimation of patients in acute stroke applying tilt-table Erigo.**
V.D. Daminov, N.V. Rybalko, I.G. Gorohova, E.V. Zimina, A.N. Kuznetsov
National Pirogov Centre of Therapy and Surgery. Moscow. Russia
- 1.4 Title to be announced.**
A. Albegova
Treatment Rehabilitation Centre, Moscow, Russia
- 1.5 Title to be announced.**
M.R. Makarova
Treatment Rehabilitation Centre, Moscow, Russia
- 1.6 Analysis of ECG and systemic arterial pressure in the cardiac cycle during selective stimulation of a left vagus nerve in a man.**
P. Pečlin, J. Rozman
ITIS d. o. o. Ljubljana, Center for Implantable Technology and Sensors, Ljubljana, Republic of Slovenia
- 1.7 Innovative rehabilitation technology in neurorehabilitation of patients in coma.**
M. Lippert-Grüner
Klinik für Allgemeine Neurochirurgie, Klinikum der Universität zu Köln
- 1.8 Is the exposure to multisensorial early rehabilitation model important for recovery of neuromotor function and scar formation after TBI? (experimental study).**
M. Lippert-Grüner, M. Maegele, D.N. Angelov
Klinik für Allgemeine Neurochirurgie, Klinikum der Universität zu Köln (Germany); Chirurgische Klinik der Universität zu Witten-Herdecke, Klinikum Köln-Merheim (Germany); Institut I für Anatomie der Universität zu Köln, Universität zu Köln (Germany)
- 2.1 Psychophysiological indicators in virtual reality-assisted motor rehabilitation.**
D. Novak, M. Mihelj, M. Munih
University of Ljubljana
- 2.2 REHAB-DUET: Bimanual Rehabilitation System for Distal Upper Extremity Therapy.**
V. Patoglu
Faculty of Engineering and Natural Sciences, Sabanci University, Istanbul, Turkey



- 2.3 Investigate Rehabilitation-Induced Recovery with fMRI-Compatible Robotics.**
N. Yu, C. Hollnagel, N. Estévez, S. Kollias, R. Riener
Sensory-Motor Systems Lab, Institute of Robotics and Intelligent Systems, ETH Zurich; Institute of Neuroradiology, University Hospital Zurich, University of Zurich; Spinal Cord Injury Center, University Hospital Balgrist, University of Zurich
- 2.4 Decoupling of synergistic movement patterns with gravity compensation and virtual reality in chronic stroke patients: preliminary results.**
T. Krabben, G.B. Prange, A.H.A. Stienen, B.I. Molier, G.J. Renzenbrink, H. van der Kooij, M.J.A. Jannink
Roessingh Research and Development, Enschede, the Netherlands; University of Twente, Dep. of Biomechanical Engineering, Enschede, the Netherlands; Physical Therapy and Human Movement ; Science, Northwestern University, Chicago, USA; Roessingh Rehabilitation Center, Enschede, the Netherlands
- 2.5 Preliminary findings of gravity compensation training in combination with a rehabilitation game in chronic stroke patients.**
GB Prange, T. Krabben, J. de Boer, GJ Renzenbrink, HJ Hermens, MJA Jannink
Roessingh Research & Development, Enschede, the Netherlands; Roessingh Rehabilitation Center, Enschede, the Netherlands; University of Twente, Institute of Biomedical Technology, Enschede, the Netherlands; University of Twente, Dep. of Biomechanical Engineering, Enschede, the Netherlands
- 2.6 Title to be announced.**
P. Pyk
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- 2.7 Title to be announced.**
R. Gassert
Rehabilitation Engineering Lab, ETH Zürich, Switzerland
- 3.1 Does Virtual Reality alter the intensity of locomotor-assisted physiotherapy? A case study examining biomechanical and electrophysiological data on the Augmented Feedback Lokomat.**
M. Sapa, F. Müller
Neurologische Klinik Bad Aibling
- 3.2 Guiding users in virtual reality rehabilitation environments using a machine learning decision system.**
I. Kastanis, M. Slater
EVENT Lab, Facultat de Psicologia, Universitat de Barcelona, Institució Catalana Recerca i Estudis Avançats (ICREA)
- 3.3 Title to be announced.**
K. Tansey
Shepherd Center, Emory University, Atlanta, USA
- 3.4 Enhance Patient Engagement in Automated Gait Training.**
M. Bolliger, A. König, L. Zimmerli, A. Duschau-Wicke, H. Vallery, V. Dietz, R. Riener
Sensory Motor Systems Lab, ETH Zurich, CH; Spinal Cord Injury Center, University Hospital Balgrist, Switzerland; Hocoma Inc., Volketswil, CH
- 3.5 Increasing Motivation in Gait Rehabilitation: A Project Outline.**
L. Zimmerli, R. Riener, L. Lünenburger
Hocoma AG, Volketswil, Switzerland; Sensory-Motor Systems Lab, Inst. for Robotics & Intelligent Systems, Dept. of



Mechanical & Process Eng., ETH Zurich, Switzerland; Spinal Cord Injury Center, University Hospital Balgrist, Faculty of Medicine, University Zurich, Switzerland

- 3.6 Virtual Reality Soccer Scenario to Enhance Active Participation of Robotic-Assisted Gait Training in Children.**
K. Brüttsch, T. Schuler, A. Koenig, L. Zimmerli, L. Lünenburger, S. Koeneke, R. Riener, L. Jäncke, A. Meyer-Heim
Neuropsychologisches Institut, Universität Zürich; Rehabilitationszentrum Affoltern a. A., Universitäts-Kinderkliniken Zürich; Labor für Senso-Motorische Systeme, ETH Zürich; Hocoma AG
- 3.7 Virtual Realities as a Motivation Tool for the Gait Training in the Pediatric Lokomat.**
T. Schuler, R. Müller, K. Brüttsch, A. Meyer-Heim
Rehabilitation Centre Affoltern a.A., University Children's Hospital, Zurich; Institute of Human Movement Sciences and Sport, ETH Zurich; Institute of Neuropsychology, University of Zurich
- 3.8 Assessment of the Cardiovascular Regulation During Lokomat® Robotic Assisted Locomotion in Normal Subjects and Stroke Victims.**
V. Magagnin, L. Fusini, M. Turiel, V. Licari, I. Bo, E.G. Caiani, S. Cerutti, A. Porta
Biomedical Engineering Department, Politecnico di Milano, Milan, Italy; Galeazzi Orthopaedic Hospital IRCCS, Milano, Italy; Department of Technologies for Health, Galeazzi Orthopaedic Institute IRCCS, University of Milan, Milan, Italy
- 4.1 Spinal reflexes and locomotion pattern in complete spinal cord injury.**
M. Hubli, V. Dietz, M. Bolliger
Spinal Cord Injury Center, Balgrist University Hospital, Zurich, Switzerland
- 4.2 Influence of reduced guidance force during Lokomat training on leg muscle activity.**
S. Estermann, L. Büttler, A. Dewor, M. Bolliger, D. Zutter
Humaine Klinik Zihlschlach, Switzerland; Spinal Cord Injury Center, University Hospital Balgrist, Zurich, Switzerland
- 4.3 Title to be announced.**
K. Hunt
Scottish Centre for Innovation in Spinal Cord Injury, Southern General Hospital, Glasgow, UK
- 4.4 Effects of Robot-Mediated Locomotor Training on EMG Activation in Healthy and SCI Subjects.**
S. Mazzoleni, G. Stampacchia, E. Cattin, E. Bradaschia, M. Tolaini, B. Rossi, M. C. Carrozza
ARTS Lab, Scuola Superiore Sant'Anna, Pontedera, Italy; Department of Neuroscience, Neurorehabilitation Unit, University of Pisa, Italy
- 4.5 Gait Training Robot Assisted Versus Conventional Walking Training in Multiple Sclerosis Subjects.**
G. Pompeo, A. Giosué, A. Clodomi, L. Mungari, C. Melegari
Anmic Riabilitazione, Crotone, Italy
- 4.6 Motor Return Facilitation in Hemiplegic CVA: Does Acupuncture Help?**
M. A. Young, B. J. O'Young, T. Chao, H. Hoffberg, S. Kolla, M. Young
Workforce & Technology Center-Maryland Rehabilitation Center (Baltimore, Maryland); New York University; SUNY Health Science Center (NY); University of Maryland-BC
- 4.7 Title to be announced.**
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Poster Abstracts

Poster 1.1

Temporal and Spatial Patterns of Cortical Activation during Lower Limb Movement.

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Human gait is a complex process in the central nervous system that results from the integrity of various mechanisms, including different cortical and subcortical structures. However, current knowledge about neural control of gait is still limited, as the measurement of the underlying cerebral activity is challenging. Therefore, a reliable real-time image of the brain structures involved in controlling human gait has not yet been accomplished. In addition, the temporal pattern of neural activity during gait cycle remains an open question.

In the present study we investigated cortical activity during lower limb movement using EEG. Assisted by the dynamic tilt table Erigo (Hocoma AG, Switzerland) all subjects performed the same standardized stepping movements in an upright position. The Erigo was tilted to 76° and leg movement was adjusted to 44 steps per minute. To reduce movement artifacts subjects were tightly fixed by a belt system. Source localization of the movement-related potential in relation to spontaneous EEG activity showed that most of the active voxels are located in classical motor regions such as the primary motor cortex, the premotor cortex and the supplementary motor cortex. Furthermore, activity was found in the cingulate cortex, the primary somatosensory cortex as well as the somatosensory association cortex. All these brain regions are classically associated with human gait.

The high temporal resolution of EEG enabled a detailed acquisition of the temporal course of cortical activity during gait-like leg movement. A clear relation between the chronological sequence of the measurement and the gait cycle was observed. The scalp topographies showed a characteristic change within positive potential differences at fronto-central locations and negative ones at parietal spots. These differences as well as the amplitude alteration on the Cz electrode could be mapped to specific phases of the gait-like leg movement.

Mapping the measured temporal and spatial patterns of cortical activation to human gait can be used for many applications in the field of neurorehabilitation or brain-computer interfaces. Detected signals can be feed into a controller that drives a neuroprosthesis based on the patient's intentions. Alternatively, training in a virtual environment may provide new promising opportunities.

Poster 1.2

Active tilting a patient to erect position within a very early period of neurorehabilitation – cardiovascular stimulation.

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Introduction: Tilting table can be an useful device in the very early period of neurorehabilitation. It allows to achieve tilting position with dynamic loading of lower extremities in a course of stepping process. Besides possibility of keeping the patient in erect position, tilting tables provide proper gate stimulation. It could also serve as a therapeutic device in stimulating cardiovascular resistance.

Material and Methods: 16 young patients without any circulatory disorders were enrolled in the test. 8 patients suffered from spinal cord injury (aged 19-36 years old) and 8 patients with brain injury (aged 14-59 years old). Circulatory and vascular parameters, as well as breath rate were measured during 30 minute training in the ERIGO table. Measurements were conducted during 5 phases of therapy, starting from the prone position, legs movement, standing

position, movement termination, movement continuation and resting.

Results: During therapy by means of tilting table, changes in heart rate, blood pressure and breath rate were observed. When the table was elevated, a small increase of HR and blood pressure was measured. Whereas by eliminating the leg movements, the prompt drop of blood pressure and increase of HR were noticed. However, the restoration of movement, restored also previous parameters. Similar changes were observed in the breath rate.

Conclusion: Tilting a patient on a tilting table with the "stepping function" leads to the stability of circulatory parameters. Stepping termination destabilizes the cardiovascular system. Thus, this therapy can be a form of cardiovascular training during the further stages of rehabilitation. In the early phase of treatment, allows for the effective and quick tilting without side effects.

Poster 1.3

Central and cerebral blood flow estimation of patients in acute stroke applying tilt-table Erigo.

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Introduction: The aim of our research was to evaluate the efficacy and safety of early mobilization of patients applying tilt table Erigo.

Methods: Forty-eight patients with hemiparesis in acute stroke were examined and divided into two groups: the 1st one included 29 patients had standard course of rehabilitation therapy and trained with the help of Erigo, 18 patients of the 2nd – control group had only standard rehabilitation program. We used 6 marks paresis degree scale and Barthel ADL Index to estimate the efficiency of rehabilitation. Hemodynamics monitoring was performed with the help of impedance cardiography and transcranial Doppler ultrasonography of damaged middle cerebral artery. Neurological inspection and hemodynamics control was spent to all the patients at base line, in the

end of the course and during the training procedure on Erigo.

Results: For the time of rehabilitation measures the middle mean of muscles strength in damaged inferior extremity increased in the 1st group patients on 1.2 marks, in the 2nd group patients on 0.5 marks. The middle mean of movement's amplitude in damaged inferior extremity increased in the 1st group patients on 23 degrees, in the 2nd group patients on 13 degrees. More significant dynamics in Barthel ADL Index was represented in the 1st group patients. After rehabilitation course there was no meaningful changes of central and cerebral blood flow indexes in both group patients. Moderate elevation of cerebral blood flow rate and decreasing of peripheral vascular resistance i.e. magnification of cerebral perfusion was fixed during the training procedure on Erigo.

Conclusion: Early mobilization with tilt table Erigo provides restoration of motor functions in larger volume, than use only standard program of rehabilitation. Arterial blood pressure and cerebral blood flow indexes remained within standard that proves the safety of the method. Application of tilt table "Erigo" has positive influence on the cerebral blood flow.

Poster 1.4

Title to be announced.

Anna Albegova

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Poster 1.5

Title to be announced.

Marina Rostislavovna Makarova

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Poster 1.6

Analysis of the ECG and systemic arterial pressure in the cardiac cycle during selective stimulation of a left vagus nerve in a man.

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ITIS d. o. o. Ljubljana, Center for Implantable Technology and Sensors, Ljubljana, Republic of Slovenia

Vagus nerve stimulation (VNS) builds on a long history of investigating the relationship of autonomic signals on limbic and cortical function. The aim of our study was to study feasibility and safety of selective stimulation of different types of fibres within particular compartments of the left vagus nerve in a man under precisely controlled conditions.

In 2 patients, the 39-electrode spiral nerve cuff was temporarily installed under general anaesthesia around the left vagus nerve after carotid end arterectomy. The relative position of the particular nerve region containing branches and nerve fibers related to the heart was identified by delivering the biphasic, cathodic first pulses with quasitrapezoidal-shaped cathodic and square anodic parts on to all thirteen group of three electrodes (GTE)s.

The stimuli, delivered to GTE1 resulted in profound slowing of the heart and a complete cessation of the heartbeat. It was shown that intensities i_c below 2.5 mA, elicited relatively small mean changes in components of ECG as well as in components of mechanical events within the cardiac cycle during left VNS. However, intensity i_c of 2.5 mA, applied before the absence of cardiac contraction, elicited significant mean changes in components of ECG. It was shown that the biggest mean change in components of ECG, were elicited with intensity i_c of 2.5 mA, applied for a short period of time after the absence of cardiac contraction. Finally, after the left VNS was terminated mean changes in components of ECG returned almost back to the values before the left VNS was applied. Furthermore, intensities i_c below 2.5 mA did not cause significant fall in Systemic Arterial Pressure (SAP) during left VNS while the left VNS with intensity i_c of 2.5 mA elicited a rapid fall in SAP and the

absence of a cardiac contraction. It could be also seen that intensity i_c of 2.5 mA, applied before the absence of cardiac contraction, elicited significant mean changes in mechanical events within the cardiac cycle during left VNS. The biggest mean change in components of mechanical events within the cardiac cycle during left VNS were elicited with intensity i_c of 2.5 mA, applied for a short period of time after the absence of cardiac contraction. Finally, it could be seen that after the left VNS was terminated, mean change in components of mechanical events within the cardiac cycle started to approach the values before the left VNS was applied. The conclusion can be drawn that function of a heart can be efficiently modulated via the selective stimulation of innervating compartment of the left vagus nerve.

Poster 1.7

Innovative rehabilitation technology in neurorehabilitation of patients in coma.

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Introduction: Significant progress in medical technology and treatment was leading to a considerable increase in the number of severe brain-injured survivors. Most of them show severe functional deficits. For rehabilitation treatment, coma-patients present a special challenge.

The multimodal early stimulation forms the basis of the therapy procedures coming for the application and offers a good possibility for the application of innovative rehabilitation technology.

Material and methods: The aim of the study is to improve the 12-months outcome in 24 severe brain injured patients with coma duration for more than seven days. All patients had received an uninterrupted rehabilitative treatment, starting in the acute phase of illness and including Multimodal-Early-Onset-Stimulation (MEOS).

The application of innovative rehabilitative technology took place particularly during vestibular, tactile and proprioceptive stimulation. For the application came different arts of tilt-table and Motomed, as well as apparative supported vibration stimulation which could be executed finally also with support the Galileo System.



Outcome after 12 months was assessed by means of Glasgow Outcome Scale (GOS) and Functional Independence Measure (FIM).

Results: 12 Months after trauma: six (25%) of the patients had died (GOS=1), three (12.5%) continued to be in a vegetative state (GOS=2), six (25%) were severely disabled (GOS=3), six (25%) were moderately disabled (GOS=4) and three (12.5%) achieved a good recovery with only minimal disability (GOS=5). Mean FIM was 88.3 (range 18–126).

Discussion and conclusion: The early onset rehabilitation is one of the most important factors for the outcome of the severe brain injured patients with a prolonged phase of coma. If patients survive the critical stage of TBI, mortality rate during the first year is still very high. Patients who survive and receive early and continuous rehabilitative treatment, despite of high number of severe neurological deficits, it is possible to get a high degree independence on care. Although the application of innovative rehabilitative technology could attain up to now only little importance in the rehabilitation, a meaningful supplement offers apparatus supported rehabilitative promotion here.

Poster 1.8

Is the exposure to multisensorial early rehabilitation model important for recovery of neuromotor function and scar formation after TBI?

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Introduction: In numerous clinical and experimental examinations could be shown that training measures and exposition of an enriched environment can lead to a change of the neuro-anatomical structure of the brain and affect the rest of sensomotorical deficits positively. A knowledge which forms the basis for all therapy procedures being used in the rehabilitation.

The present study was designed to determine whether exposure to multisensorial early rehabilitation model (RM) after moderate traumatic brain injury (TBI) in rats would promote the recovery of neuromotor function and leads to a reduction of scar formation superior to that under standard conditions (SC).

Materials and Methods: Male Sprague-Dawley rats (n = 32) were subjected to either lateral fluid percussion (LFP) brain injury or sham operation. Thereafter, half of the animals (injured and sham operated) were placed under standard conditions (SC) without stimulation, and the other half underwent early multisensorial RM.

Motor function was assessed by using a composite neuroscore (NS) test battery at 24h, 7, 15 and 30 DPI. This was followed by evaluation of the expression of GFAP (astrocyte marker) on 15 and 30 DPL.

Results: Neuromotorfunction assessed by NS was markedly reduced in both injured groups at 24h post-injury being non-significant. However, animals in the injured/RM group performed significantly better when tested for neuromotorfunction as compared to injured/SC animals on 7d, 15 d and 30d DPI (7d: p = 0,005; 15d: p < 0,05).

In parallel, quantitative estimation of immunohistochemical staining for GFAP showed significantly smaller lesion volume in the RM rats than in the SC animals at 15DPL (14.77 ± 4.58 mm³ vs. 26.56 ± 4.57 mm³) and at 30 DPL (6.76 ± 3.08 mm³ vs. 8.99 ± 2.44 mm³).

Conclusion: This report of post-traumatic treatment indicates that exposure to RM may reduce CNS scar formation and reverse neuromotor deficits after TBI in rats.

Poster 2.1

Psychophysiological indicators in virtual reality-assisted motor rehabilitation.

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University of Ljubljana

Psychophysiology, the science of estimating psychological states from physiological responses, has become a common tool in psychology, ergonomics and human-computer interaction. However, physiological indicators of stress and concentration are also influenced by all types of physical workload, so psychophysiology has so far remained limited to situations with little or no required physical effort. We present a preliminary study of the feasibility of using



psychophysiological responses in upper limb rehabilitation. Thirty healthy participants performed an inverted pendulum balancing task using a virtual environment and the HapticMaster haptic interface that has shown promise in reaching and grasping rehabilitation. The task was performed several times, with two possible levels of physical workload and three possible difficulty levels. The highest difficulty level was designed to be impossibly hard in order to induce stress. Additionally, a control task was performed where the participants moved their arm in the absence of a virtual environment. Heart rate, skin conductance, respiratory rate and peripheral skin temperature were recorded during the tasks. Measurements taken during a rest period served as the baseline. The principal objective of the study was to identify the ability of each physiological response to indicate general mental arousal and stress independently of the level of physical workload. The frequency of skin conductance responses was significantly higher during the inverted pendulum task than during the control task for both levels of physical load, indicating a connection with general mental arousal. Skin temperature was independent of physical workload and only decreased during the highest task difficulty level, indicating a major influence of stress. Respiratory variability was lowest during normal difficulty and highest during high difficulty, indicating an influence of both general arousal and stress. Both heart rate and heart rate variability were predominantly affected by physical workload and showed no difference between the control and pendulum tasks. These patterns have also been observed in studies of environments with no physical effort, so physiological responses may be useful for estimation of stress and general mental arousal even in situations with a moderate level of physical workload.

Poster 2.2

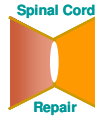
REHAB-DUET: Bimanual Rehabilitation System for Distal Upper Extremity Therapy.

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Although beneficial effects of robot-assisted rehabilitation over conventional therapy have been demonstrated through clinical trials, the success of early robot-assisted rehabilitation systems have been far from expectations. Limited success of early implementations of rehabilitation systems is attributed to the human-machine interface established by the control design of these devices that does not allow active involvement of patients. Specifically, many of these devices employ robots as non-accommodating trajectory generators, while the patients are expected to behave as passive subjects. Even though such passive paradigms are effective in treating secondary concerns such as muscle weakness, the primary goal of physical therapy for neurological injuries, that is, inducing plastic recovery of neural control systems in the brain and the spinal cord, is not properly addressed. Emphasizing the importance of active involvement of patients in the physical therapy routine, we developed a bimanual rehabilitation system with assistance methods that allow patients to practice self-induced robotic therapy through use of their intact arms.

In particular, we designed a force-feedback exoskeleton targeting forearm and wrist movements and implemented bilateral control paradigms, so that patients can guide and control the physical assistance provided to their injured extremity using their intact arm. During physical therapy, patients drive the master interface to elicit forces from the slave device to provide mechanical assistance to the impaired arm and to achieve coordinated movement. The coupling between the healthy arm and the impaired arm is bilateral to promote a higher degree of involvement of the intact arm, stimulating the central nervous system and to enable better task performance while completing functional therapy. Using the proposed interface, patients can control the amount and duration of mechanical assistance provided during therapy. Moreover, the scaling factor coupling the intact and injured extremity to the task can be modulated based on performance to ensure that the patient is exposed to an appropriate amount of haptic guidance.



Poster 2.3

Investigate Rehabilitation-Induced Recovery with fMRI-Compatible Robotics.

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Many patients suffering from neurological damages have shown the capability of regaining some lost functions over time. This is due to brain plasticity that neuronal damage is associated with a marked reorganization of the activation patterns of specific brain structures. Therefore, controllable, reproducible sensorimotor stimuli together with functional magnetic resonance imaging procedures will yield better scientific understanding of the human sensorimotor system, and, thus, contribute to preclinical therapy evaluation, medical treatment and rehabilitation. The research objectives of this project are to: develop mechatronic devices and robotic systems that are able to work compatibly fMRI procedures; apply the robotic system with fMRI to investigate cortical reorganization after neurological damage and systematically study the cortical correlates of rehabilitation-induced behavioral recovery; propose effective neurorehabilitation strategies.

An one-degree-of-freedom fMRI-compatible robot has been built up to perform sensorimotor tasks during fMRI procedures. This robot is actuated by a hydrodynamic cylinder. A self-developed optical force sensor measures the push and pull force from the user, and an optical encoder measures position. With appropriate control strategies, we have realized two operation modes. In the subject-passive mode, the subject is guided by the robot to follow a defined position trajectory, and the movement pattern, range and speed can be adjusted for individual subjects. In the subject-active mode, the subject can push or pull actively against the robot, while the robot simulates a spring or damper or spring-damper system. The

spring stiffness and dampening coefficient can be adjusted according to the subject's functional capability. Preliminary fMRI studies with six healthy subjects have shown that brain sensory-motor areas were successfully stimulated during subject-passive movements, and were activated in a higher degree in subject-active movements. A recognized problem during the fMRI experiments is head motion. A subject showed significant head motion and his data had to be excluded from fMRI analysis.

Motor and sensory neuroimaging paradigms will be refined and validated in healthy subjects, based on the movements being trained. Comprehensive neurological and mathematical models describing the anatomical and physiological relationships will be proposed and evaluated. Novel rehabilitation strategies will be suggested for neurological patients.

Poster 2.4

Decoupling of synergistic movement patterns with gravity compensation and virtual reality in chronic stroke patients: preliminary results.

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Introduction: Many stroke subjects suffer from impaired motor control. Often, the ability to perform independent movements is decreased, and synergistic movement patterns are observed. Effects of these unwanted couplings between movements of the shoulder and elbow can be reduced instantaneously by applying gravity compensation. However, it is not clear how training in a gravity compensated environment affects coupling of movements of the upper extremity in the unsupported condition.

Methods: For a period of six weeks, four chronic stroke subjects with moderate to severe hemiparesis, received three 30 minute training sessions per week. During each training session a game called FurballHunt was played, in which the user had to chase away little birds. During the game the arm

was supported by a passive gravity compensation device (Freebal). Initial and post-training motor control were evaluated during unsupported clockwise and counter clockwise circle drawing, by recording joint angles of the shoulder and the elbow. Movement within and out of synergistic patterns were characterized by identifying simultaneous shoulder abduction/adduction and elbow flexion/extension. Also the area of the circles drawn before and after the training period was evaluated.

Results: After training, all subjects increased their active range of motion, as indicated by the area of the drawn circles. Subjects also increased the ability to move out of the flexion synergy (simultaneous shoulder abduction and elbow extension) during clockwise circle drawing in the unsupported condition. During counter clockwise circle drawing an increased ability to move out of the extension synergy (simultaneous shoulder adduction and elbow flexion) was observed. All subjects decreased the amount of single joint movements after training.

Conclusions: these preliminary results indicate that a short period of moderately intense, arm rehabilitation training in a gravity compensated, virtually augmented environment can lead to decoupling of synergies during unsupported movements of chronic stroke patients with moderate to severe hemiparesis. As a result the active range of motion is increased, which may lead to functional improvement of the affected arm.

Poster 2.5

Preliminary findings of gravity compensation training in combination with a rehabilitation game in chronic stroke patients.

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Introduction: After stroke, arm function is limited in a majority of stroke survivors. A variety of sensory and motor symptoms can contribute to a reduced ability to coordinate movements. This can be expressed by a reduction in the selectivity of movements, as has been observed in the case of involuntary coupling of shoulder abduction and elbow flexion, reducing the extent of reach. Arm support, or gravity compensation, reduces the required amount of shoulder abduction, which results in a larger range of motion instantaneously. However, the effect of a longer-term application of gravity compensation on reach performance is largely unknown. During training, motor relearning processes can be stimulated by implementing a motivating rehabilitation game.

Methods: Six weeks of reach training, with a total of 18 sessions of 30 minutes, was provided for 4 chronic stroke patients with moderate to severe hemiparesis (initial Fugl-Meyer scores ranging from 10 to 46 points). Gravity compensation was implemented by a passive device (Freebal) via springs and cables attached to slings for the arm. Reaching exercises were practiced using a rehab game based on motion capturing, in which birds had to be chased away by movements of the arm (FurballHunt). During evaluation sessions pre and post training, maximal forward directed reaching movements were performed without gravity compensation. Hand position, joint rotations and muscle activation were recorded during those maximal reaching movements.

Results: After training, motor status had improved in 3 of the 4 stroke patients by at least 9.8%. In addition, reach distance increased by at least 5% along with elbow extension excursions in 2 of these patients. These increases in range of motion were accompanied by an increase in activity of the triceps and anterior deltoid muscles (prime movers) in 3 out of 4 patients.

CONCLUSION: The present findings indicate that unsupported reach performance and agonist muscle activity can increase after only moderate intensity gravity compensation training. It is thought that a reduction of the involuntary coupling between shoulder abduction and elbow flexion is involved in these changes after gravity compensation training. The present explorative study implies that gravity compensation training, in combination with a motivating game environment, is a promising tool for stroke rehabilitation to enhance reach performance in chronic stroke patients with moderate to severe hemiparesis.

Poster 2.6

Title to be announced.

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Poster 2.7

Title to be announced.

Roger Gassert

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Poster 3.1

Does Virtual Reality alter the intensity of locomotor-assisted physiotherapy? A case study examining biomechanical and electrophysiological data on the Augmented Feedback Lokomat.

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Neurologische Klinik Bad Aibling

Rationale: One common therapeutic approach for patients with gait disorders due to paresis – whether caused by stroke or spinal cord injury – is robot-assisted treadmill training on devices such as the Lokomat. Recent projects examine the effect of multimodal feedback, including audiovisual virtual reality displays, on motivation of both patients and therapists, training intensity and outcomes.

One long-term project taking this approach is the EU-funded MIMICS study (<http://www.mimics.ethz.ch>), enhancing the Lokomat robotic driven-gait orthosis by adding audiovisual displays. Furthermore, real-time psycho-physiological and biomechanical data are analyzed and used for automated adjustment of training parameters.

Currently, little data exist on the relevance of VR displays on objective measures of activity in the affected limb.

Methods: In the first iteration of the protocol, we used an Augmented Feedback Lokomat to capture biomechanical data. Our hypothesis was that virtual reality feedback causes the patient to increase exercise intensity, resulting in increased torque affecting the robot.

Subjects were six individuals (2 healthy controls, 2 incomplete paraplegics after spinal cord injury, 2 right-hemispheric insults). We measured torque and angle using the built-in sensors of the Lokomat. All individuals had been exposed to Lokomat training, including VR-augmented feedback, before. Walking speed was set at 2km/h, the guidance force reduction was set individually to optimize the probands gait pattern. The data was measured on-line during training. For off-line analysis, we cut the data at the maxima of the angle amplitude. The resulting movement phases of 10 consecutive steps were averaged; the resulting force and angle time series were compared both between individuals and intra-individually according to feedback status (VR vs. conventional Lokomat training) and training condition (walk a straight line, turn left, turn right).

Results: We could not show a significant enhancement of measured torques during VR training nor a systematic response pattern to the different conditions. However, the intra-individual analysis indicates that some patients use reduction / enhancement of the forces on the healthy leg to steer the avatar while maintaining constant low-level activity of the affected side. Initial results of a second iteration of the protocol with surface-EMG measures of affected muscles will be presented at the meeting.

Poster 3.2

Guiding users in virtual reality rehabilitation environments using a machine learning decision system.

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The aim of this work is to use an automatic decision making system in order to adapt parameters of a virtual environment (VE) in real-time according to the participant's psycho-physiological measurements and an underlying therapeutic goal. The decision making system uses Reinforcement



Learning (RL) which is based on the idea of rewarding appropriate actions in order to maximise a long term reward. Traditional RL approaches aim to maximise a reward function based on the state of the system itself. In this work our aim is to indirectly control the behaviour of the human participant via the actions of computer controlled elements of the virtual environment. The reward function in our approach is derived from the psycho-physiological state of the participant. The system learns which actions will lead the participant, instead of the system itself, towards a desirable state. An initial study to examine this methodology has been designed in order to guide people to various locations within the VE without ever explicitly instructing them to go to these locations. A virtual humanoid character (avatar) controlled by the decision making system decides how to pull the human participant to pre-selected targets. The participant and the avatar are connected with a virtual rope. In this study the avatar learns which actions will bring the human to the target and thereby maximising its own internal reward. The decision making system is trained in advance using simulations. Furthermore, it can still adapt its decision strategy while it is in use in real-time. For the purposes of this experiment we use the Wii balance board for navigation within the VE. The balance board detects the centre of gravity of the participant and this is mapped to a navigation controller. The participant is therefore able to navigate within the radius of the virtual rope as well as resist the pulling force of the rope. The goal of this experiment is to prove the validity of the methodology and serve as a guide for further studies based on more advanced psychophysical states of the participant.

Poster 3.3

Title to be continued.

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Poster 3.4

Enhance Patient Engagement in Automated Gait Training.

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Robotic systems perform their tasks by means of a variety of control loops. In classical physical human-robot interaction, the biomechanics of humans form parts of these control loops. However, integrating the human into the loop can be considered not only from the biomechanical viewpoint but also from novel physiological and even psychological aspects. Biomechanical integration involves ensuring that the system to be used is safe and "patient-cooperative". Applied to rehabilitation robotics, this means that the robot applies forces in a compliant way so that the patient can contribute to movements with own voluntary effort. Thus, the robot should only assist just as much as needed. Physiological integration involves recording and controlling the patient's psycho-physiological reactions. Patients should always receive appropriate stimuli, which involve them in a moderate but engaging way and do not cause undue stress or harm. If future interface technologies for rehabilitation can face these challenges, they may substantially increase the efficacy and efficiency of robot-aided therapeutic training.

Poster 3.5

Increasing Motivation in Gait Rehabilitation: A Project Outline.

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Walking is important for participation in daily social activities. Rehabilitation after injuries of the nervous system and other



causes of gait dysfunction usually includes gait training. While the technology used in gait rehabilitation has evolved during the last decade from conventional treadmills to modern gait orthoses like the Lokomat, new concepts that target the motivational aspects of patients have emerged from the field of virtual reality (VR) and entered motor rehabilitation. Since frequent repetition of a task comprising the affected body part is considered to be the most effective method for motor (re-)learning, patients must be highly motivated to practice the same movements over and over again. VR represents an ideal tool for rehabilitation since it not only can incorporate the same movements in various contexts i.e. different virtual scenarios, making therapy more diverse, but also gives online feedback to patients about their current performance. Despite a large and growing number of VR applications and studies in upper extremity rehabilitation, only few studies have been conducted in gait therapy. The aim of this project is to create an Augmented Feedback application for the Lokomat that addresses motivational aspects of patients by balancing the difficulty of therapy tasks with the individual's capabilities. The difficulty level of the scenarios will thus be adjusted online in order to create the appropriate challenges for every patient depending on his or her current level of ability. This may be similar to the methods called dynamic difficulty adjustment used in the field of entertainment media. To what extent these methods might improve the outcome of current therapy will still have to be assessed.

Poster 3.6

Virtual Reality Soccer Scenario to Enhance Active Participation of Robotic-Assisted Gait Training in Children.

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Background: Virtual environments can make repetitive motor rehabilitation exercises more motivating and thereby more effective. Children in particular show insufficient motivation towards the training process, as the regular training might be too monotonous and lacks stimulation entertainment. Therefore, we developed a virtual reality (VR) based soccer scenario that provided interactive elements to engage patients during robot-assisted treadmill training.

Aim: The aim of the study was to compare the immediate effect on motor output during different supportive conditions (therapists instruction versus VR scenario) in patients and healthy control children while training with the Lokomat gait orthosis.

Method: Ten patients (four males, six females, mean age 14.6 years, std. 3 years) with different neurological gait disorders and eight healthy children (two males, 6 females, mean age 12.6 years, std. 3.3 years) were instructed to walk on the Lokomat in four different randomly presented conditions: (1) walk normally, (2) therapists' instruction to promote active walking, (3) VR as motivating tool to walk actively, and (4) VR tool combined with therapists' instruction. The measured motor output is expressed by force exertion provided by the Lokomat gait orthosis. Additionally, subjects' acceptance about the Lokomat training with VR was assessed by questionnaire.

Results: Active participation in patients and control children increased significantly when supported and motivated either by therapists' instruction or by VR scenario compared with reference measurement (normal walking) ($p < 0.0001$). There were no differences between patients and healthy subjects in all four conditions.

Discussion: In conclusion, the used VR scenario induces an immediate effect on motor output that is of similar magnitude as the effect resulting from verbal instructions by therapist. Therefore, VR represents a valuable tool for patients and healthy subjects to keep motivation high during Lokomat training. Further development needs to focus on the implementation of interactive design elements that keep the motivation high across and beyond Lokomat training sessions especially in pediatric rehabilitation.



Poster 3.7

Virtual Realities as a Motivation Tool for the Gait Training in the Pediatric Lokomat.

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Background: Motivation has been recognised as an important factor in pediatric rehabilitation. Children often show insufficient motivation during the locomotion training due to the monotony and long duration of the stepping practise. Therefore, real-time running virtual realities (VR) were developed for the therapy in the pediatric robotic driven gait orthosis (DGO) Lokomat. These allow more interaction in the training and enhance the gaming aspect of a task. The aim of this study was to evaluate the VR as a motivation tool to keep children highly engaged during gait training and to find out the therapist's role in that process.

Method: Nine handicapped and eight healthy children participated in the practical experiment and all filled out an intrinsic motivation inventory (IMI) and a self-generated questionnaire for the training with VR. The muscular effort was assessed by a surface electromyography (SEMG) on four muscles during the training. Children were randomly assigned in two different protocols with six different task conditions. These tasks included: a normal walking task in the DGO, walking with therapist's motivational instructions, a VR soccer scenario, the soccer game with additional therapist's instructions, a VR landscape scenario, and a walk on a normal treadmill without the DGO. The Outcome Measures of interest were the motor output expressed by mean muscle activity and the participant's motivation assessed by two different questionnaires. Comparisons were drawn through repeated measurement Analysis of Variance (ANOVA) and paired-parametric t- tests.

Results: The logarithmic transformed data show that the EMG activity output in both groups was strongly higher during tasks with VR than the normal walking

condition ($P < 0.001$ for the soccer game). Both groups demonstrated higher muscle activity with therapeutical instructions ($P < 0.001$).

A connection between self reported motivation, effort and fun (questionnaires) and behavioural indices (muscle activity) was observable.

Conclusion: Our results support that both, the VR scenarios and the therapist seem to be an efficient motivation tool to increase children's muscular effort in the pediatric Lokomat. The gaming aspect of VR helps to keep children's interest high during repetitive tasks.

Poster 3.8

Assessment of the Cardiovascular Regulation During Lokomat® Robotic Assisted Locomotion in Normal Subjects and Stroke Victims.

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Body weight supported (BWS) treadmill training assisted with robotic driven gait orthosis is an emerging clinical tool helpful to restore gait in individuals with loss of motor skills. The clinical implications of its utilization are focused on the motor-rehabilitation, however it appears important to consider the effects of this rehabilitation strategy on the autonomic response and on the cardiovascular system. In fact, long-time periods of reduced or absent overall activity level due to the onset of invalidating diseases, cause a significant reduction in heart rate variability (HRV) and an increased probability of adverse cardiac events.

Accordingly, our first aim. Indeed, protocols that are too much demanding in terms of cardiovascular system response should be avoided in patients recovering after stroke or after spinal cord injury.

Accordingly, twas to evaluate the autonomic nervous system response during a traditional protocol of motor rehabilitation with Lokomat® through spectral and symbolic analyses of short-term HRV in a group of 20 normal healthy subjects! The protocol was composed by the following phases: sitting position; standing position; suspension during subject

instrumentation; robotic assisted treadmill locomotion at 1.5 km/h and 2.5 km/h respectively with partial BWS; standing recovery after exercise. The same experimental protocol was then applied to 5 stroke victims in correspondence of the first and the last of 30 daily Lokomat® sessions, in order to assess not only the response of the autonomic system control to the specific rehabilitative protocol but also the cardiovascular long-term effects of BWS treadmill training on the autonomic regulation of heart rate. Results showed a significant tachycardia associated with the reduction in variance indicated during the suspended phase of the protocol compared to the sitting position on normal subjects. In the same group, symbolic analysis was able to detect an increase in sympathetic modulation during body suspension and an increase of vagal modulation during walking phases, which were reciprocal but with different magnitude.

Results on stroke victims showed non uniform behavior between the patients in any sympathetic or vagal modulated index during the different protocol phases recorded during the first day of rehabilitation. Conversely, it was possible to notice a general decrease in vagal mediated indexes during the standing and suspended phases, and a trend towards increasing during the walking phases compared to rest, during the last Lokomat® session. These findings provide a better comprehension of the cardiovascular effects of rehabilitation in subjects undergoing robotic driven gait orthosis treadmill training and could be utilized for a better definition of the duration of the rehabilitation period necessary to improve the autonomic nervous system response and consequently to positively influence the cardiovascular system.

Poster 4.1

Spinal reflexes and locomotion pattern in complete spinal cord injury.

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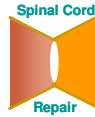
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Background: Changes in spinal locomotor circuitries in patients with complete spinal cord injury (cSCI) are often investigated by analyzing spinal reflexes (SR). SR are used as a neural window into spinal networks and consist of two components, an early (latency 60 – 120 ms) and a late one (latency 120 – 450 ms). Specific research in patients with cSCI has been done to assess the time course of SR. Since a cSCI often causes a disruption between brain centers and spinal networks SR undergo changes, i.e. a shift from early to late SR with time of chronicity. However, more investigation of the connection of SR pathways to locomotion networks and their neuronal pathways is needed. Therefore, the aim of this study was to investigate the influence of the early and late SR pathways on locomotion activity.

Methods: Stepping movements in complete para-/tetraplegic patients were induced by a driven gait orthosis (DGO) on a treadmill. All subjects were unloaded by 70% of their own body weight. The influence of SR, evoked by tibial nerve stimulation, on leg muscle activity during assisted walking within the DGO was analyzed. SR were evoked at mid-stance phase of the gait cycle. EMG recordings were made of representative bilateral proximal and distal leg muscles, i.e. rectus femoris (RF), biceps femoris (BF), tibialis anterior (TA) and gastrocnemius medialis (GM).

Results: In 4 of 18 patients only late SR appeared and their locomotion pattern during SR elicitation differed in contrast to patients with early SR components. Patients with functioning early SR pathways (as in healthy subjects) showed an increased muscle activation in TA due to electrically evoked limb flexion. However, in patients with only late SR pathways an unnatural disturbance of normal locomotion pattern due to electrical stimulation became visible. Especially in RF and TA an increased muscle activity occurred due to stimulation which differed from normal locomotion pattern in non stimulated steps.

Conclusion: Our data are consistent with the assumption that early and late SR components belong to different neuronal pathways. It can be concluded that these two different pathways have a distinct influence on the locomotion pattern generator.



Poster 4.2

Influence of reduced guidance force during Lokomat training on leg muscle activity.

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Objective: Because of the lower metabolic costs and muscle activity in robotic assisted stepping compared to therapist assisted stepping, methods to increase the patients active participation during robot assisted walking should be found (1). To achieve this, the driven gait orthosis (DGO) Lokomat offers a tool to reduce guidance force (GF) during walking. We investigated the influence of GF on leg muscle activity, measured by surface EMG amplitude.

Hypothesis: Reduction of GF increases EMG amplitude.

Methods: Surface electromyography of 4 muscles (tibialis anterior, gastrocnemius medialis, rectus femoris, biceps femoris) on each leg of 7 healthy subjects (age: 25.4±3) was measured. GF was changed in randomized order (10-100%) during robot assisted walking in the Lokomat without bodyweight support. Muscle activity was quantified by calculating the root mean square (RMS) of each EMG signal and after residual analysis an ANOVA for repeated measures was used. Pairwise comparisons were Bonferroni corrected.

Results: Tests of fixed effects revealed a significant influence of GF on RMS in stance and in swing phase ($p < 0.001$). This influence was not different between muscles, there was no interaction between muscle and GF. In pairwise comparisons GF 10% and 20% in swing phase and in stance phase GF 10% and 30% showed different mean values compared to GF 100% ($p < 0.01$).

Conclusion: GF increased leg muscle activity in healthy subjects walking in the DGO in healthy subjects, but GF has to be very low for significant effects. In practice we see that patients with neurological gait disorders have problems to walk with

such low support. Further investigations have to be done to determine the influence of GF on leg muscle activity and to assess the feasibility of robotic assisted gait training with very low GF in patients with neurological gait disorders.

(1) Israel et al.: Metabolic costs and muscle activity patterns during robotic- and therapist- assisted treadmill walking in individuals with incomplete spinal cord injury. Phys. Ther. 2006; 86.

Poster 4.3

Title to be announced.

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Poster 4.4

Effects of a Robot-Mediated Locomotor Training on EMG Activation in Healthy and SCI Subjects.

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Twelve healthy control subjects, aged 23-61 (mean age 30.1±11.2), eight men and four women, and two male SCI subjects, aged 34-44 (mean age 39.0±7.1), a paraparetic due to transverse myelitis and a paraparetic due to a post-traumatic D7 incomplete lesion, respectively, were recruited. Stepping movements on a treadmill were induced and assisted by an exoskeletal robotic system, the Lokomat driven gait orthosis (DGO) (Hocoma AG, Switzerland). All subjects underwent a surface electromyographic (sEMG) examination. Each subject, after providing informed consent, performed both a robot-assisted exercise and unassisted treadmill exercise, at three velocities: 1.0, 1.6 and 2.4 km/h, at 30% BWS. Each subject was instructed to walk in three different conditions: (i) passively (i.e. stepping movements induced by the Lokomat), in order to reduce the physical interaction with



the robotic system ("Passive" mode), (ii) actively walk, as normal as possible, within the DGO, in order to cooperate with it ("Active" mode), (iii) walking on the treadmill without the DGO ("Without" mode). The sEMG electrodes were attached to both subject's leg. The heel strike timing was acquired using two customized foot-switches, taped directly to the subject's heels. Muscular activity was recorded using a 16 channels sEMG system (TeleMyo 2400, Noraxon USA, Inc., Scottsdale, AZ). The sEMG signals were recorded from rectus femoris (RF), biceps femoris (BF), tibialis anterioris (TA), and medial gastrocnemius (GA). They were processed using a custom software (Matlab, Mathworks Inc., Natick, MA, USA).

SCI subjects underwent a Lokomat training for 4 weeks, 3-5 sessions per week, duration of each session was 45 minutes.

The subjects were assessed before ("Pre-training"), after the training ("Post-training") and after three months ("Follow-up"), through both a clinical assessment and the same test protocol applied to healthy subjects.

The results presented in this study also show how the robot-assisted therapy using the Lokomat system in two SCI patients elicits their muscular recruitment. The improved muscular activity, which relies on the voluntary effort and the remaining natural control mechanisms after a spinal cord lesion, at the end of the Lokomat training, can be considered as the main benefit to the patients. Moreover, these benefits are maintained even three months after the end of the robotic training.

The muscular recruitment during the "Active" mode, both before and after the Lokomat training, gains the evidence about the positive patient-robot interaction: a statistical analysis on a larger dataset will be soon performed in order to confirm these results.

Poster 4.5

Gait Training Robot Assisted Versus Conventional Walking Training in Multiple Sclerosis Subjects.

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Poster 4.6

Motor Return Facilitation in Hemiplegic CVA: Does Acupuncture Help?

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Facilitative techniques have been traditionally used in stroke rehabilitation to promote motor recovery. Acupuncture has been practiced in China for over 3 millennia as an effective technique in promoting stroke motor recovery. To date, the possible role of acupuncture in facilitating motor return in hemiplegic stroke patients has not been extensively investigated in the United States. To assess the efficacy of acupuncture in improving upper extremity paralysis following ischemic cortical CVA, we treated a group of five ischemic stroke patients with acupuncture using a standardized meridian approach. We compared this cohort with a group of age-matched patients who did not receive acupuncture intervention. Fugl-Meyer motor scores and ADL scores were recorded before and after initiation of treatment. Highlighted in this pilot study are details concerning the specific treatment paradigm used to treat ischemic stroke patients. This poster presentation will include a literature review of acupuncture's role in the stroke population. Also highlighted will be a literature review of possible neurophysiological and neural recovery mechanisms that may account for motor recovery in the acupuncture treated hemiplegics.

Poster 4.7

Title to be announced.

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