Principles of New Technologies
Reasons for New Technologies

Societal drivers

- Ageing of population
- Cost of health care
- Burden in daily life

Technological drivers

- Available technology
- Fast growing
- Home use

Clinical drivers

- Unused recovery potential
- Evidence-based knowledge
New technologies for enhanced and effective therapy … … and assessing recovery progress
Clinicians design assessments and treatment programs using the technologies to improve patient’s rehabilitation.
Potential influence of New Technologies

Principles of New Technologies

Advanced Rehabilitation Technology

Movement & sensory input

Muscle strength

Varied, goal oriented repetitions at limit of performance & Feedback from successful performance

Improved performance

Reduce support
Increase challenge

Neuroplasticity
Motor Learning

Potential influence of New Technologies
Contents

1. Robot-assisted Therapy
2. Non-actuator Devices
3. Functional Electrical Stimulation (FES)
4. Sensor Technology
5. Virtual Reality
6. Brain Stimulation
1

ROBOT-ASSISTED THERAPY
Rehabilitation Robotics

“Rehabilitation Robotics has been defined a special branch of robotics which focuses on machines that can be used to help people recover from severe physical trauma or assist them in activities of daily living.”
History and Future of Rehabilitation Robotics, Frumento et al. 2010

- Idea of using robots for rehabilitation emerged during the 1980’s
  - Free therapists from heavy, repetitive work
  - Increase consistency and volume of repetitions

Concept:

(industrial) robot + arm/leg orthosis = therapeutic robot
Robotic Therapy: Elements

Mechanical structure
• Moveable segments and joints

Actuators
• Convert energy into motion and force, e.g. motors

Sensors
• Measure physical parameters, e.g. position, force, orientation, torque

Controller
• Uses sensor data to control actuators

Patient interface
• Attaches to patient and transmits forces from the robot, e.g. cuffs

User interface
• Enables user to adjust controller settings

Power source
• Provides electricity to drive actuators, controller
Robotic Therapy: Devices

How to categorize robot-assisted therapeutic devices?

**Mechanical structure**
- Exoskeletons
- End-effector-based

**Attachment Location**
- Upper limbs
- Lower limbs

**Control strategies**
- Full guidance
- Patient-cooperative
- Free Space
Robotic Therapy: Exoskeletons

“A wearable robot or external structural mechanism with joints and links corresponding to those of the human body.”

Pons et al., 2006; History and Future of Rehabilitation Robotics, 2010

- Attached to body or body parts
- Joints transmit forces to different robotic segments
- Allows production of physiological movements
- Combination with treadmills, body-weight-support, functional electrical stimulation, virtual reality
Robotic Therapy: End-Effector Devices

“Robotic devices that provide support and forces to the patient’s limb only at its most distal part (end effector) which is attached to patient’s extremity.”

Maciejasz et al., 2014

- Attached to single body segment
- Transmit force via mechanical movement chain
- Combination with treadmills, body-weight-support, functional electrical stimulation, virtual reality

Upper limbs

Lower limbs
Exoskeletons vs. End-Effector Devices

**Exoskeleton**
- Joint axes fully determined
- Physiological movements
- Force and position data of each joint
- Robot axes have to align with anatomical axes
- Longer set-up times
- Challenging anatomical constraints

**End-effector-based**
- Simpler structure / control
- Easy to adjust to patient
- Limb posture not fully determined
- Limited force / position data
- Risk of joint injury
Robotic Therapy: Upper Limbs

Laterality

- Unilateral: Parethric or unaffected arm individually
- Bilateral: Both arms together

Degrees of freedom

- Amount of degrees of freedom
- 2 DoF
- 6+1 DoF

Individual limbs

- Elbow
- Finger
- Single limbs
- Combination of limbs
Robotic Therapy: Lower Limbs

Gait training

- **treadmill**
  - Automated body-weight support training
  - Exoskeleton combined with treadmill

- **foot-plates**
  - Automated body-weight support training
  - End-effector based device

- **overground**
  - Body-weight support follows patient
  - Allows natural walking but requires muscle activity

- **active orthoses**
  - Support position and motion control of leg joints
  - Compensate for weakness and deformities
Robotic Therapy: Control Strategies

**Full guidance**
- Predefined motion performed by robot
- Muscle activity not required

**Patient-cooperative control**
- Guided movements
- Partial support to initiate and perform movement
- Haptic simulation for interactive environment

**Free space**
- Negligible interaction with robot
# Robotic Therapy: Advantages I

<table>
<thead>
<tr>
<th>Robot-assisted Therapy</th>
<th>Conventional Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supports therapist</td>
<td>Limited by manpower</td>
</tr>
<tr>
<td>High reliability</td>
<td>Poor movement repeatability</td>
</tr>
<tr>
<td>High amounts of repetitions / intensity</td>
<td>Limited number of repetitions</td>
</tr>
<tr>
<td>Individually adjustable assistance</td>
<td>Difficult for severely affected patients</td>
</tr>
</tbody>
</table>
Robotic Therapy: Advantages II

<table>
<thead>
<tr>
<th>Robot-assisted Therapy</th>
<th>Conventional Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantifiable and objective assessments</td>
<td>Imprecise or subjective assessments</td>
</tr>
<tr>
<td>Highly motivating for some</td>
<td>Motivation dependent on patient therapist relationship</td>
</tr>
<tr>
<td>Detailed and timed sensory feedback</td>
<td>Subjective feedback</td>
</tr>
<tr>
<td>New interventions</td>
<td></td>
</tr>
</tbody>
</table>
### Robotic Therapy: Limitations

<table>
<thead>
<tr>
<th>Robot-assisted Therapy</th>
<th>Conventional Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costly (short-term)</td>
<td>Less costly (short-term)</td>
</tr>
<tr>
<td>Space consuming</td>
<td>No big space requirements</td>
</tr>
<tr>
<td>Risk of obsolescence</td>
<td>No risk of obsolescence</td>
</tr>
<tr>
<td>Devices specific for individual limbs</td>
<td>Treatment of any body part</td>
</tr>
<tr>
<td>Lacks degree of feedback or flexibility</td>
<td>High degree of feedback or flexibility</td>
</tr>
<tr>
<td>Limited communication</td>
<td>Communication dependent on therapist</td>
</tr>
</tbody>
</table>
Linkage to Neural Principles and Learning

**Repetitions**
- More repetitions
  - Automated administration
  - Assistance

**Practice Time**
- Increased practice time
  - Less need for supervision
  - Higher motivation

**Optimal Difficulty Level**
- Individually adjustable difficulty
  - Added resistance
  - Decreased support/assistance
Linkage to Neural Principles and Learning

Segmentation

- Simplified part practice
  - Bilateral/unilateral
  - Partial movements
  - Reduced degrees of freedom

Motivation

- Increased motivation
  - success through assistance

Feedback

- Various feedback forms
  - Inherent and augmented haptic feedback
  - Assistance as-needed
2

NON-ACTUATOR DEVICES
Non-Actuator Devices

Non-actuator devices emerged from improvement ideas for robotic therapy

- Decrease device complexity and cost
- Increase safety for patients
- Improve training of functional movements and activities of daily living

Concept:

therapeutic robot - actuators/motors = non-actuator devices
Non-Actuator Devices: Elements

Weight support
- Static balancing mechanisms using links, springs or wires

Sensors
- Measure physical parameters, e.g. position, force, orientation, torque

Patient interface
- Attaches to patient and transmits forces from the device, e.g. cuffs

User interface
- Enables user to adjust controller settings
Non-Actuator Devices: Upper/Lower Limbs

Upper limbs

- Arm weight support against gravity
- Ellbow, finger or wrist joint support

Lower limbs

- Static body weight support against gravity
- Hip, knee or ankle joint support
Non-Actuator vs. Robotic Devices

**Non-actuator devices**
- Significant lower costs
- Less weight
- Easier to use and intrinsically safe
- No power source needed
- No support other than against gravity
- No movement correction
- Limited resistance

**Robotic devices**
- Movement guidance for optimal trajectory
- Full movement support even for severely impaired patients
- Adjustable resistance
- Expensive and heavy
- More complex to use
- More safety precautions needed
### Non-Actuator Devices: Advantages

<table>
<thead>
<tr>
<th>Non-actuator Devices</th>
<th>Conventional Therapy</th>
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<tr>
<td>Supports therapist</td>
<td>Limited by manpower</td>
</tr>
<tr>
<td>Higher amount of repetitions / intensity</td>
<td>Limited number of Repetitions</td>
</tr>
<tr>
<td>Assistance against gravity</td>
<td>Assistance against gravity with therapist</td>
</tr>
<tr>
<td>Quantifiable and objective Assessments</td>
<td>Imprecise or subjective Assessments</td>
</tr>
<tr>
<td>Highly motivating for some</td>
<td>Motivation dependent on patient therapist relationship</td>
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<tr>
<td>Detailed and timed sensory feedback</td>
<td>Subjective feedback</td>
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</table>
## Non-Actuator Devices: Limitations

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<tr>
<th>Non-actuator Devices</th>
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</tr>
<tr>
<td>Lacks degree of feedback or flexibility</td>
<td>High degree of feedback or flexibility</td>
</tr>
<tr>
<td>Limited communication</td>
<td>Social interaction</td>
</tr>
</tbody>
</table>
3

FUNCTIONAL ELECTRICAL STIMULATION (FES)
Functional Electrical Stimulation

Electrical stimulation that results in coordinated muscle contractions and generate functional movements such as standing, walking, or grasping is called functional electrical stimulation (FES).

Dietz et al. 2012, Neurorehabilitation Technology

- Originated from electrotherapy
- Originally used in neuroprostheses to substitute impaired function
- Only usable if nerves and muscles are intact

Concept:

\[
\text{muscle} + \text{electricity pattern} = \text{functional electrical stimulation}
\]
FES: Elements

Stimulator
• Determines simulation strength (current or voltage), frequency and length

Electrodes
• Apply voltage to skin

Power source
• Provides electricity to give stimulation
FES: Stimulation Parameters

- **Pulse frequency**
  - High enough required (smooth contractions vs. series of twitches)
  - Higher frequency results in stronger contractions but muscles tires quickly
  - Ideal frequency: 12-16 Hz (upper) and 18-25 Hz (lower)

- **Pulse amplitude/duration**
  - Increasing pulse amplitude or duration increases strength of contraction
  - Too high amplitudes activate pain nerves
  - Duration of 200-400 us
FES: Electrodes

Surface electrodes
- noninvasive
- medium conducting current to underlying skin (e.g. water, conductive gel)

Subcutaneous electrodes
- percutaneous
  - inserted through skin
  - temporary
- implanted
  - implanted under skin
  - permanent
### FES: Surface Electrodes

<table>
<thead>
<tr>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non invasive method</td>
</tr>
<tr>
<td>Multiple muscles can be stimulated with a single electrode</td>
</tr>
<tr>
<td>Easy to apply and generally inexpensive</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor selectivity</td>
</tr>
<tr>
<td>No option of stimulating deeper located muscles</td>
</tr>
<tr>
<td>Variable stimulation response needing time to reposition electrodes</td>
</tr>
<tr>
<td>Higher voltage required</td>
</tr>
</tbody>
</table>
## Advantages

<table>
<thead>
<tr>
<th>Percutaneous</th>
<th>Implanted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good selectivity</td>
<td></td>
</tr>
<tr>
<td>Constant stimulus perception response</td>
<td></td>
</tr>
<tr>
<td>Lower voltage required</td>
<td></td>
</tr>
</tbody>
</table>

## Disadvantages

<table>
<thead>
<tr>
<th>Percutaneous</th>
<th>Implanted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Invasive surgery</td>
</tr>
<tr>
<td></td>
<td>Safety (risk of infection, broken electrode parts)</td>
</tr>
</tbody>
</table>
**FES: Application**

<table>
<thead>
<tr>
<th>Neuroprotheses</th>
<th>Neuromodulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lost functions (walking, grasping) are restored by using electrical signals to replace motor commands or afferent signals</td>
<td>Nerve activity is altered through the delivery of electrical stimulation to normalize or modulate nerve function.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Open-loop</th>
<th>Closed-loop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preprogrammed stimuli without sensory feedback</td>
<td>Sensory feedback adjusts stimulus intensity in order to control movement</td>
</tr>
</tbody>
</table>
## FES: Advantages and Limitations

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production of ‘natural movements’</td>
<td>Muscle fatigue</td>
</tr>
<tr>
<td>Replaces impaired or lost feedback</td>
<td>Skin irritation</td>
</tr>
<tr>
<td>Prevention of muscle atrophy, increase in strength</td>
<td>Variable stimulus tolerance, pain</td>
</tr>
<tr>
<td>Usable at home</td>
<td>Electrode placement difficulty</td>
</tr>
</tbody>
</table>
4

SENSOR TECHNOLOGY
Sensor Technology

“*A device that measures or detects a real-world condition, such as motion, heat or light and converts the condition into an analog or digital representation.*”

Free Online Encyclopedia

Altered demographics raise some fundamental questions:
- How do we care for an increasing number of individuals with complex medical conditions?
- How do we provide quality care to those in areas with reduced access to providers?
- How do we maximize the independence and participation of an increasing number of individuals with disabilities?

Concept:

\[
\text{sensor} + \text{display} = \text{sensor technology}
\]
Sensor Technology: Elements

Sensing and data collection hardware
• To collect physiological and movement data

Communication hardware and software
• To relay data to a remote center

Data analysis techniques
• To extract clinically-relevant information from physiological and movement data
Sensor Technology: Key Enabling Factors

- **Communication Technology**
  - Low-power
  - Wireless standards

- **Micro Fabrication**
  - Miniaturization
  - System-on-chip
  - Low cost

- **Mobile Technology**
  - Gateway
  - Localization
  - Computation
Sensor Technology: Field of Application

Diagnostic applications
- Physiological sensing

Monitoring applications
- Biochemical sensing

On-going treatment
- Motion sensing
Sensor Technology in Rehabilitation I

Health and wellness

Activity monitoring

«Aging in place»

Safety monitoring

Fall/seizure detection

Home rehabilitation

Combination of virtual reality

Therapeutic exercise

Principles of New Technologies 44
Sensor Technology in Rehabilitation II

**Assessment of treatment efficacy**

By knowing what happens between outpatient visits, treatment interventions can be fine-tuned to the needs of individual patients.

**Early detection of disorders**

Achieve early detection of changes in patient’s status requiring clinical intervention.

**Disease management**

**Patient status**
## Sensor Technology: Advantages and Limitations

<table>
<thead>
<tr>
<th><strong>Advantages</strong></th>
<th><strong>Limitations</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Affordable for majority of patients</td>
<td>Technical barriers such as limitations of currently available battery technology</td>
</tr>
<tr>
<td>Solve patient access issues (patients living far away from therapy centre)</td>
<td>Cultural barriers associated with the use of medical devices for home-based clinical monitoring</td>
</tr>
<tr>
<td>Increase patient independence and participation</td>
<td></td>
</tr>
</tbody>
</table>
VIRTUAL REALITY
“Virtual reality typically refers to the use of interactive stimulations created with computer hardware and software to present users with opportunities to engage in environments that appear to be and feel similar to real-world objects and events.”

Weiss et al. 2004

Idea of using virtual reality for rehabilitation emerged during the mid to late 1990s

- Defined trajectory in virtual environment had to be reproduced by patients (Holden et al. 1999)
- Increase motivation and simplify feedback information (knowledge of performance)

Concept:

user input/tracking device + display = virtual reality
Model of VR-based rehabilitation

The goal is to help the patient achieve participation in the real world environment by overcoming, adapting to or minimizing the environmental barriers.

- **Real world**: Performance in real world
- **Transfer phase**: Task performance within virtual environment
- **«Interaction space»**: Activity
- **Participation**: Transfer of trained skills or tasks as well as environmental modifications from the virtual environment to the real world.
Virtual Reality: Elements

Hardware components
- Primary user input (Keyboard, Mouse, Joystick/3D Pointing Devices/Whole-hand and body input)
- Tracking interface (Measure head, body, hand or eye motion)
- Visual, auditory, haptic interface

Software components
- Input process
- Simulation process
- Rendering process
- World database
## Virtual Reality: Hardware

### Head-Mounted Display (HMD)
- Helmet or mask providing visual and auditory stimuli
- LCD or CRT for stereo images.
- Option of built-in head-tracker and stereo headphones

### Binocular Omni-Oriented Monitor (BOOM)
- Head-coupled stereoscopic display device
- CRT for high-resolution
- Built-in tracking

### Cave Automatic Virtual Environment (CAVE)
- Projection of stereo images on a room-sized cube
- Head tracking continuously adjust the projection to the current position of the leading viewer

### Data Glove
- Sensors on fingers plus position/orientation tracking
- Enables natural interaction with virtual objects

### Control Devices
- Control virtual objects in 3 dimensions (Joystick, mouse)
Virtual Reality: Software (Architecture)

- Input processor
- Stimulation processor
- Rendering processor

Position & Orientation

Visual, Auditory, Haptic

Principles of New Technologies
Virtual Reality: Fields of Application

- Design, engineering, manufacturing and marketing
- Hazardous operations in extreme or hostile surroundings
- Training in military and industrial machine operation, medical teaching and surgery planning/training
- Medicine and healthcare
### Virtual Reality: Devices

<table>
<thead>
<tr>
<th>Immersive</th>
<th>Non-Immersive</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total-body movement</strong></td>
<td><strong>Non total-body movement</strong></td>
</tr>
<tr>
<td>Motion capture via camera/video</td>
<td>Interaction via keyboard, mouse, joystick</td>
</tr>
<tr>
<td>Motion capture via sensor device</td>
<td></td>
</tr>
</tbody>
</table>

#### Rehabilitation specific

- Rehabilitation specific
  - Commercially available

#### Head mounted display

- Force feedback gloves
  - Camera detects users’ body movements

#### Fully immersed; first person view

- Mirror-image reflection
  - Represented as an avatar or user invisible; 1st person or 3rd person view

- Mouse, joystick or keyboard
  - Represented as an avatar or user invisible; 1st person or 3rd person view

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**Principles of New Technologies**
Virtual Reality: Immersive Devices

“The goal of Immersive VR is to completely immerse the user inside the computer generated world, giving the impression to the user that he/she has “stepped inside” the synthetic world.”

Furht 2008, Encyclopedia of Multimedia

- First person view of 3D virtual world
- Users wears head mounted display
- Feel of presence
- Virtual scene is responding to the subjects action
Virtual Reality: Non-Immersive Devices

“In non-immersive systems, the VR system often consists of a computer monitor, mouse, keyboard and possibly joysticks, haptic devices and force sensors.”

Ortiz-Catalan et al., 2014

- Use of monitor to display the visual world
- Interact through motion detecting interfaces
- Subjects do fully respond in the real environment
Virtual Reality: Advantages

<table>
<thead>
<tr>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensive training (repetition) and increased motivation by feedback</td>
</tr>
<tr>
<td>information</td>
</tr>
<tr>
<td>Improve approach efficacy and outcome by making tasks easier, less</td>
</tr>
<tr>
<td>demanding and less tedious</td>
</tr>
<tr>
<td>VR environments are flexible and customizable for different therapeutic</td>
</tr>
<tr>
<td>purposes</td>
</tr>
</tbody>
</table>
# Virtual Reality: Limitations

## Limitations

<table>
<thead>
<tr>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of standards, frameworks and compatibility</td>
</tr>
<tr>
<td>Dizziness, headache, cyber sickness</td>
</tr>
<tr>
<td>Legal aspects: registration as medical device</td>
</tr>
<tr>
<td>High costs - fully immersive systems</td>
</tr>
</tbody>
</table>
Linkage to Neural Principles and Learning

Motivation

- Motivation is needed to repetitively carry out task

Feedback

- Learning process must be reinforced by feedback
- Feedback links patient’s performance to successful task outcome

Repetitions

- Repetitions are important to promote motor learning and cortical plasticity
BRAIN STIMULATION
Brain Stimulation

Brain stimulation is a technique that applies direct (electrodes) or indirect (magnetic coil) electrical stimulation to a population of neurons in the brain.

Adapted from Wikipedia

- First century AD Roman physician Scribonius Largus applied electric torpedo fish to patients’ bodies to treat headaches.
- Scientific research originated from electrotherapy in the early 19th century.
- Potential for treating depression, chronic pain, help recover faster from strokes etc.

Concept:

\[
\text{brain} + \text{electricity} = \text{brain stimulation}
\]
Brain Stimulation: Elements

**Stimulator**
- Determines stimulation strength, frequency and length

**Electrodes or magnetic coil**
- Apply voltage to skin or magnetic field

**Power source**
- Provides electricity to give stimulation
Brain Stimulation: Methods

Noninvasive

Transcranial magnetic stimulation (TMS)

Transcranial direct current stimulation (tDCS)

Invasive

Deep brain stimulation (DBS)

Magnetic coil & magnetic field

Electrodes & current

Electrodes & current
Brain Stimulation: TMS

A noninvasive technique that consists of a magnetic field emanating from a wire coil held outside the head. The magnetic field induces an electrical current in nearby regions of the brain.

MedicineNet.com

**Principle:**
- Activates or suppresses activity in cortical regions
- Repetitive TMS outlasts stimulation period up to hours
- Allows accurate mapping of muscle representation
- Useful for characterizing CNS injuries
- Causes resting neurons to fire
Brain Stimulation: tDCS

A noninvasive technique which uses constant, low current delivered directly to the brain area of interest via small electrodes.

Adapted from Wikipedia

**Principle:**

- Modulation of brain activity that can be applied before or during practice.
- Anodal region: depolarizes neuronal membrane, making it more likely to fire.
- Cathodal region: hyperpolarizes neuronal membrane, making it less likely to fire.
- Believed to modulate firing rate of active neurons
## TMS vs. tDCS

<table>
<thead>
<tr>
<th>Transcranial magnetic stimulation</th>
<th>Transcranial direct current stimulation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TMS</strong></td>
<td><strong>tDCS</strong></td>
</tr>
<tr>
<td>• Lasts up to hours</td>
<td>• Lasts up to hours</td>
</tr>
<tr>
<td>• Good spatial and temporal</td>
<td>• In general low-cost</td>
</tr>
<tr>
<td>resolution (ms)</td>
<td>• Low risk of adverse effects</td>
</tr>
<tr>
<td>• Well established protocols</td>
<td>• Reliable sham condition</td>
</tr>
<tr>
<td>• Expensive</td>
<td>• Poor spatial and temporal resolution</td>
</tr>
<tr>
<td>• Risk of seizures (rare)</td>
<td>• Concurrent modulation of brain area</td>
</tr>
<tr>
<td>• Limited to superficial brain</td>
<td>under reference electrode</td>
</tr>
<tr>
<td>areas</td>
<td>• Protocols less established</td>
</tr>
<tr>
<td>• Can result in transient</td>
<td>• Can result in transient headaches</td>
</tr>
<tr>
<td>headaches</td>
<td></td>
</tr>
<tr>
<td>• No good sham condition</td>
<td></td>
</tr>
</tbody>
</table>
Contact

International Industry Society In Advanced Rehabilitation Technology (IISART)

General Information
info@iisartonline.org
www.iisartonline.org
Image sources

Slide 2 – Audience

Slide 3 – Reasons for New Technologies
Left: http://www.unece.org/typo3temp/pics/8346dca955.jpg
Middle (upper): http://emergingtech.tbr.edu/sites/default/files/styles/flexslider_full/public/NewTech_0.jpg?itok=WghHlgJ0
Middle (lower): http://timpexelectronics.com/wp-content/uploads/2014/03/Electronics-0000166421891-1100x732.jpg
Right: http://www.nature.com/sc/journal/v41/n12/fig_tab/3101518f1.html

Slide 4 – Usage of New Technologies
1st image (motor learning): http://www.vi-hotels.com/typo3temp/pics/s_lad5ac9b5b7.jpg
3rd image (therapy): Hocoma

Slide 9 – Rehabilitation Robotics
Light bulb: http://theosophy.net/forum/topics/theosophists-and-the-light
Robot: http://bsiswoyo.lecture.ub.ac.id/files/2011/12/puma560-1.png
Arm/leg orthosis: http://www.broadendedhORIZONS.com/powergrip-add-on-kit
Image sources

Slide 10 – Robotic Therapy: Elements
Image (Lokomat): Hocoma

Slide 11 – Robotic Therapy: Devices
2nd image (Armeo Power): Hocoma
4th image (Lokomat): Hocoma
5th image (Gentle/S): http://www.reading.ac.uk/AcaDepts/si/gentle/103-0325.IMG.JPG
6th image (Mime): http://www.rehab.research.va.gov/jour/00/37/6/images/BURG-F03.JPG
7th image (G-EO System): http://www.skoutasmedical.gr/portal/components/com_virtuemart/shop_image/product/G EO System Eval 4f47675b831c.jpg
8th image (Gait Trainer): http://www.reha-stim.de/cms/assets/images/6T-1-mit-Person
9th image (Bi-Manu-Track): http://www.reha-stim.de/cms/assets/images/Bi-Manu-Track-09.jpg
10th image (Lokohelp): http://www.woodway.de/images/productimages/LokoHelp_with_PPS.png

Slide 12 – Robotic Therapy: Exoskeletons
Images: Created for slide pool

Slide 13 – Robotic Therapy: End-Effector Devices
Images: Created for slide pool

Slide 14 – Exoskeletons vs. End-Effector Devices
Images: Created for slide pool

Principles of New Technologies
### Image sources

**Slide 15 – Robotic Therapy: Upper Limbs**
- Middle images (6+1 Dof): Hocoma
- Right images (elbow): [Link to image](http://nyp.org/img/enewsletters/e100_patient_balls.jpg)
- Right images (fingers): [Link to image](http://tyromotion.com/wp-content/uploads/2013/02/Amadeo_1.png)

**Slide 16 – Robotic Therapy: Lower Limbs**
- Treadmill: Hocoma
- Foot-plates: [Link to image](http://www.rehatechnology.com/upload/cms/user/G-ED_System_brochure_EN.pdf, page 4)
- Overground: [Link to image](http://cl.staticflickr.com/5/4083/5169846467_b25ee3cc73_n.jpg)
- Active foot orthoses: [Link to image](http://www.mdpi.com/robotics/robotics-03-00120/article_deploy/html/images/robotics-03-00120-g007-1024.png)

**Slide 17 – Robotic Therapy: Control Strategies**
- Images: Adapted from Teasell and Hussein 2013, *Evidence-Based Review of Stroke Rehabilitation: Background Concepts in Stroke Rehabilitation*

**Slide 18-20 – Advantages and Limitations**
- Icons: Created for slide pool
Image sources

Slide 21 – Linkage to Neural Principles and Learning
Left image (repetitions): Hocoma
Right image (difficulty): Existing presentation

Slide 22 – Linkage to Neural Principles and Learning
Left image (segmentation): Created for slide pool
Middle image (motivation): Created for slide pool
Right image (feedback): Existing presentation

Slide 24 – Non-Actuator Devices
Light bulb: http://theosophy.net/forum/topics/theosophists-and-the-light
Middle image (actuator): http://www.intelligentactuator.com/images/rcp2_ral0c.jpg

Slide 25 – Non-Actuator Devices: Elements
Left Image: Hocoma

Slide 26 – Non-Actuator Devices: Upper/Lower Limbs
1st image: Hocoma
2nd image (handsOME): http://cabrr.cua.edu/res/images/research/Handsomepic6.jpg
3rd image (GBO): http://roar.me.columbia.edu/projects/gbo/figures/gbo.jpg
Image sources

Slide 26 – Non-Actuator Devices: Upper/Lower Limbs

Slide 27 – Non-Actuator vs. Robotic Devices
Images: Created for slide pool

Slide 28-30 – Advantages and Limitations
Icons: Created for slide pool

Slide 31 – Functional Electrical Stimulation
Light bulb: http://theosophy.net/forum/topics/theosophists-and-the-light
Electricity pattern: http://i.kinja-img.com/gawker-media/image/upload/s--v9hJogQH--/c_fit.f_h_progressive.q_80.w_636/187bzswgphpil0jpg.jpg

Slide 32 – FES: Elements
Image: IISART Techindex

Slide 33 – FES: Stimulation Parameters
Upper image: From Fuglevand et al. 1999, Force-frequency and fatigue properties of motor units in muscles that control digits of the human hand.
Lower image: From Kesar et al. 2008, Effects of stimulation frequency versus pulse duration modulation on muscle fatigue.
Image sources

Slide 34 – FES: Electrodes

Slide 35-36 – Electrode Types
Icons: Created for slide pool

Slide 38 – Advantages and Limitations
Icons: Created for slide pool

Slide 40 – Sensor Technology
Light bulb: http://theosophy.net/forum/topics/theosophists-and-the-light
Sensor: Hocoma
Display: http://clipartist.net/svg/monitor-screen-may-2011/
Sensor technology: Hocoma

Slide 41 – Sensor Technology: Elements
Image: Hocoma

Slide 43 – Sensor Technology: Field of Application
Icons: Created for slide pool
Image sources

Slide 44 – Sensor Technology in Rehabilitation I
Images: Presentation from Clemens

Slide 45 – Sensor Technology in Rehabilitation II
Icons: Created for slide pool

Slide 46 – Sensor Technology: Advantages and Limitations
Icons: Created for slide pool

Slide 48 – Virtual Reality
Light bulb: http://theosophy.net/forum/topics/theosophists-and-the-light
User input/tracking device: http://i-am-fast.com/Pictures/data-glove.jpg
Display: http://clipartist.net/svg/monitor-screen-may-2011/
Virtual reality: IISART Technindex

Slide 50 – Virtual Reality: Principles
Original slide: Prof. Dr.-Ing. Robert Riener, ETH Zurich

Slide 51 – Virtual Reality: Elements
Image: IISART Technindex

Slide 52 – Virtual Reality: Hardware
BOOM: http://www.macs.hw.ac.uk/~hamish/9ig2/graphics/t3boomhf.GIF
Image sources

Slide 52 – Virtual Reality: Hardware
CAVE: http://www.jvrb.org/past-issues/3.2006/589/figure03.jpg
Data glove: http://i-am-fast.com/Pictures/data-glove.jpg
Control devices: http://cdn2.sbnation.com/assets/3757533/hydra-theverge-1_560.jpg

Slide 53 – Virtual Reality: Software (Architecture)
Icons: Created for slide pool

Slide 54 – Virtual Reality: Field of Application
Icons: Created for slide pool

Slide 55 – Virtual Reality: Devices
Icons: Created for slide pool

Slide 56 – Virtual Reality: Immersive Devices
Image: Created for slide pool

Slide 57 – Virtual Reality: Non-Immersive Devices
Image: Created for slide pool

Slide 58-59 – Advantages and Limitations
Icons: Created for slide pool
Image sources

Slide 66 – Brain Stimulation: tDCS

Slide 67 – TMS vs. tDCS
TMS: http://www.brainclinics.com/dynamic/media/l/images/rTMS_Figure1.png
http://www.drmueller-healthpsychology.com/i//tDCS_Device.jpg

http://www.drmueller-healthpsychology.com/i//tDCS_Device.jpg