Guided Self-Rehabilitation in a Holistic ICF-Based Framework: Integrating Motor and Cognitive Recovery

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IRCCS San Raffaele

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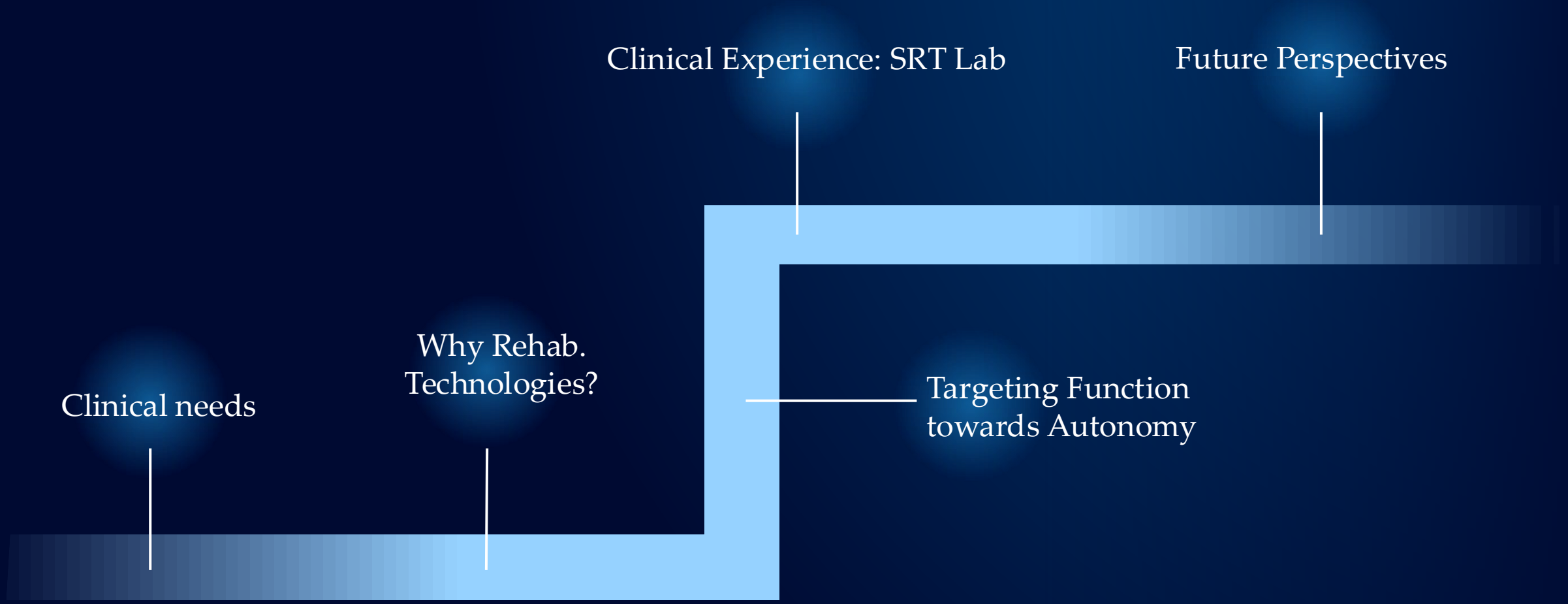
Roadmap


Clinical Experience: SRT Lab
Future Perspectives
Why Rehab. Technologies?
Clinical needs
Targeting Function towards Autonomy

IRCCS San Raffaele Excellence in Research & Rehabilitation

🎖️ IT National Benchmark

Scientific Institute for Research, Hospitalization and Healthcare - IRCCS San Raffaele is a private center accredited by the Italian Ministry of Health, national leader in neuromotor rehabilitation, integrating clinical excellence and translational research to deliver personalized, evidence-based care.

🔬 30 Research Laboratories aimed at Translational Research

The integration of care and research reaches its peak in the 30 laboratories, aimed at translating basic research into real-world clinical practice.

Life after Neurological Injury

ACTIVITIES OF DAILY LIVING

These relate to the ability to use the upper limbs.

GAIT

Rehabilitation of the lower limb to regain autonomy of free movement.

STROKE

COGNITIVE

Recovery of the ability to express oneself and understanding of what is happening

BALANCE

Prevention of the risk of falls to which patients may be susceptible

Beyond Motor Impairment

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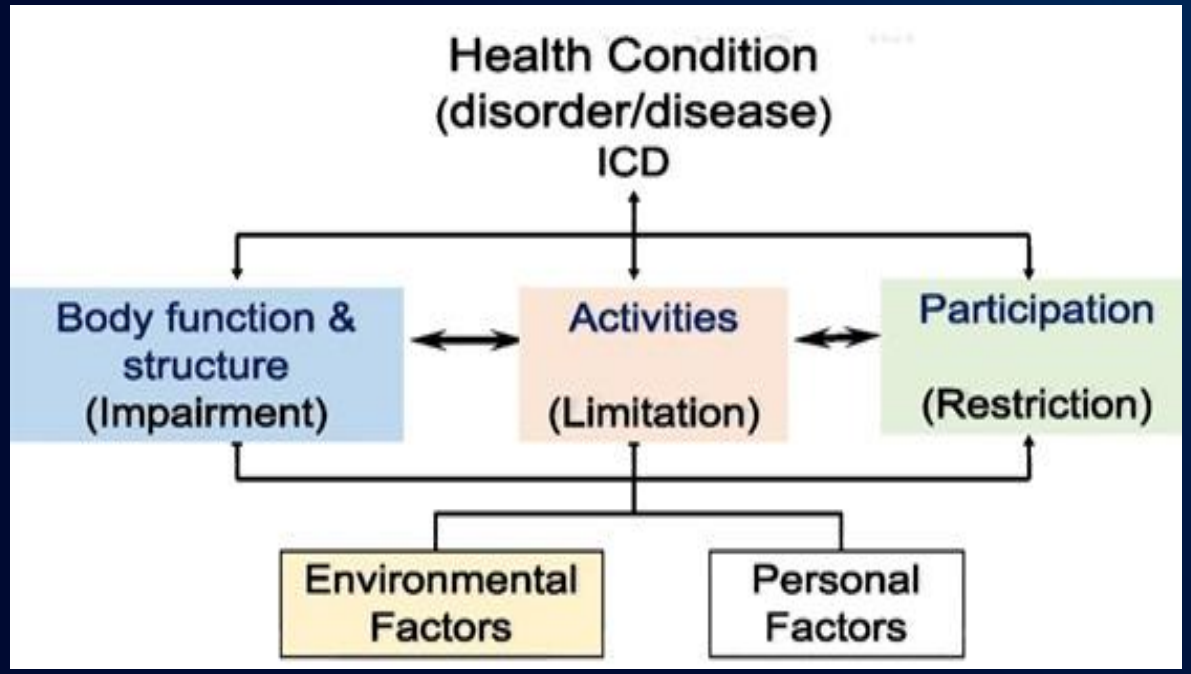
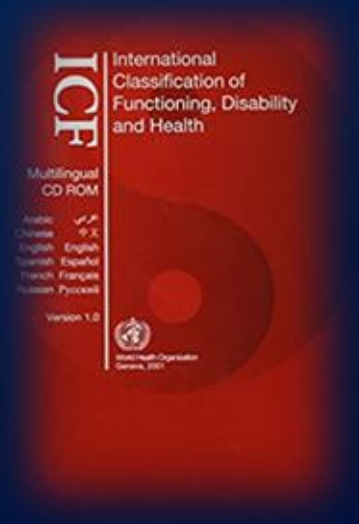
Biopsycosocial Model

Motor and **Cognitive** Functions → **ADL Performance** → **Participation** in Social Life → Percived **Quality of Life** (QoL)





ICF Conceptual Framework

Neuroplasticity

Repetitions
+ **Task-Oriented**

Intensity + **Active participation**

Multi-sensory **feedback** + **Motivation**

Neuroplasticity stimulation + **Moror Re-Learning**

Mehrholz et al., The Cochrane Library, 2021
Donnellan-Fernandez et al. J Stroke Cerebrovasc Dis. 2022

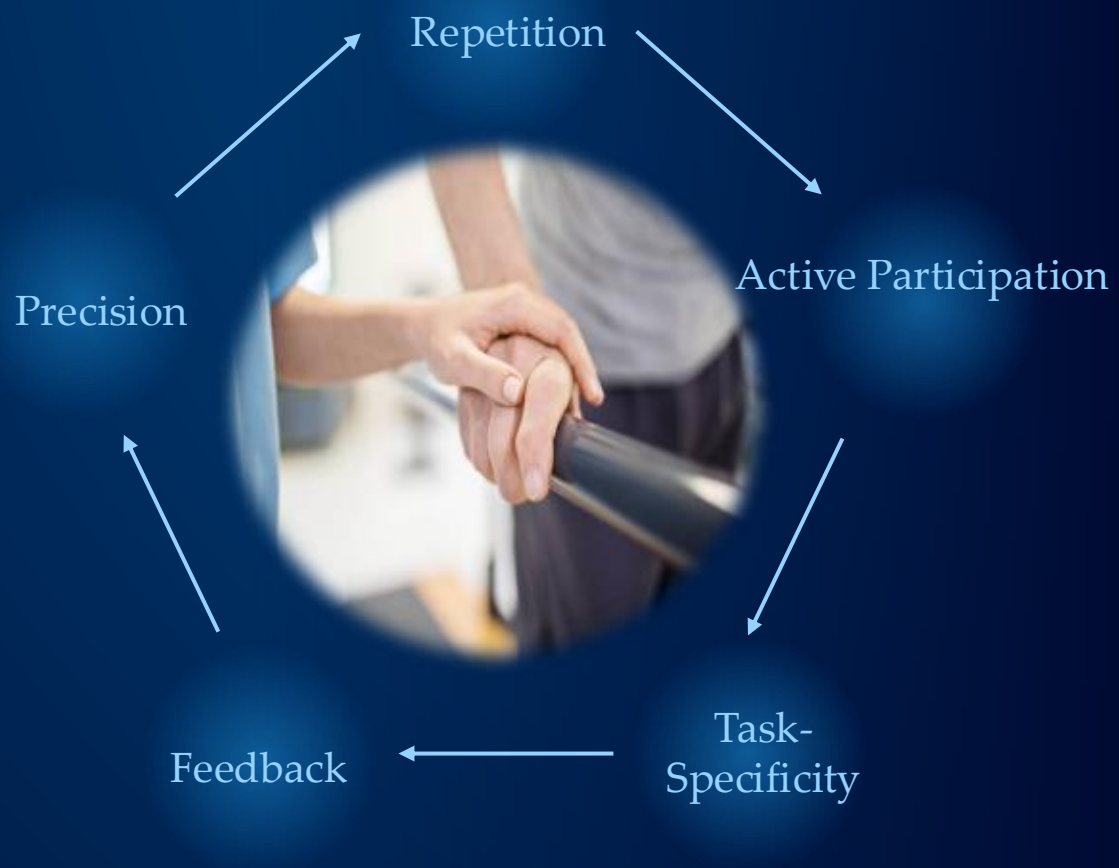
Why Technology-Enhanced Self-Rehabilitation?

Supporting Rehab Technologies

- Enables repetitive, high-intensity, **active training**
- Leads multisensory-driven cortical **engagement**
- Optimizes therapist effort without compromising quality

From Support to Augmentation

Exercise prepares the system, but behavior shapes recovery



Mehrholz et al., The Cochrane Library, 2021

Our Experience

2009

To evaluate the effectiveness of end-effector robots (proximal and distal).


J Rehabil Med 2009; 41: 971–975

ORIGINAL REPORT

ROBOT THERAPY FOR FUNCTIONAL RECOVERY OF THE UPPER LIMBS: A PILOT STUDY ON PATIENTS AFTER STROKE

Federica Bovolenta, MD[1], Milena Goldoni, PT[1], Pierina Clerici, PT[1], Maurizio Agosti, PT[2] and Marco Franceschini, MD[3]

UNER

Recovery of hand function with robot-assisted therapy in acute stroke patients: a randomized-controlled trial

Sale, Patrizio; Mazzoleni, Stefano; Lombardi, Valentina; Galafate, Daniele; Massimiani, Maria P.; Posteraro, Federico; Damiani, Carlo; Franceschini, Marco Less

Identification of kinematic parameters obtained from robotic devices as predictive factors of motor recovery.


frontiers in Bioengineering and Biotechnology

Research Article

Kinematic Parameters for Tracking Patient Progress during Upper Limb Robot-Assisted Rehabilitation: An Observational Study on Subacute Stroke Subjects

frontiers in Neurology

Stroke

To assess the feasibility of implementation in a real-world clinical setting.


Journal of Clinical Medicine

MDPI

Article

Robot-Assisted Training for Upper Limb in Stroke (ROBOTAS): An Observational, Multicenter Study to Identify Determinants of Efficacy

Rocco Salvatore Calabrò [1,†], Giovanni Morone [2,†], Antonino Naro [3], Marialuisa Gandolfi [4], Vitalma Liotti [5], Carlo D'aurizio [5], Sofia Straudi [6], Antonella Focacci [7], Sanaz Pournajaf [8], Irene Aprile [9], Serena Filoni [10], Claudia Zanetti [11], Maria Rosaria Leo [11], Lucia Tedesco [12], Vincenzo Spina [13], Carmelo Chisari [13], Giovanni Taveggia [14], Stefano Mazzoleni [15], Nicola Smania [4], Stefano Paolucci [7], Marco Franceschini [8,*] and Donatella Bonaiuti [16]

To evaluate the clinical and neurophysiological effectiveness of a 3D exoskeleton robot.


American Stroke Association.

Stroke

brain sciences

ORIGINAL CONTRIBUTION

Neurophysiological and Clinical Effects of Upper Limb Robot-Assisted Rehabilitation on Motor Recovery in Patients with Subacute Stroke: A Multicenter Randomized Controlled Trial Study Protocol

Exoskeleton-Assisted Therapy Enhances Upper Limb Motor Recovery in Early Subacute Stroke: A Multicenter, Single-Blind Randomized Controlled Trial

2026

Identification of clinical characteristics as predictive factors of ADL recovery.


PLOS ONE

RESEARCH ARTICLE

Predictors of activities of daily living outcomes after upper limb robot-assisted therapy in subacute stroke patients

Marco Franceschini[1,2*], Michela Goffredo[1*], Sanaz Pournajaf[1*], Stefano Paravati[1*], Maurizio Agosti[2*], Francesco De Pisi[1*], Daniele Galafate[1*], Federico Posteraro[4*]

To evaluate the long-term effects of end-effector robots (follow-up study)


Contents lists available at ScienceDirect

Journal of Bodywork & Movement Therapies

journal homepage: www.elsevier.com/jbmt

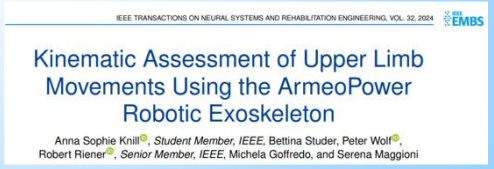
LONGITUDINAL STUDY · Volume 24, Issue 1, Pages 198, January 2020

Download Full Issue

Upper limb robot-assisted rehabilitation versus physical therapy on subacute stroke patients: A follow-up study

Marco Franceschini [a,b] · Stefano Mazzoleni [c,d] · Michela Goffredo [d] · Sanaz Pournajaf [d] · Daniele Galafate [d] · Simone Criscuolo [d] · Maurizio Agosti [d] · Federico Posteraro [d,f] Show less

To assess the validity of measurements obtained from a 3D exoskeleton

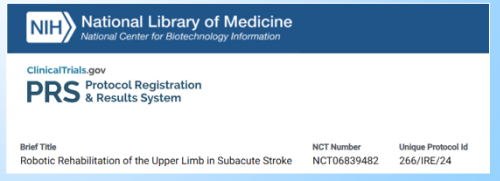

IEEE TRANSACTIONS ON NEURAL SYSTEMS AND REHABILITATION ENGINEERING, VOL. 32, 2024

EMBS

Kinematic Assessment of Upper Limb Movements Using the ArmeoPower Robotic Exoskeleton

Anna Sophie Knill, *Student Member, IEEE*, Bettina Studer, Peter Wolf, Robert Riener, *Senior Member, IEEE*, Michela Goffredo, and Serena Maggioni

To evaluate the clinical and neurophysiological effectiveness of the robotic glove


NIH National Library of Medicine

National Center for Biotechnology Information

ClinicalTrials.gov

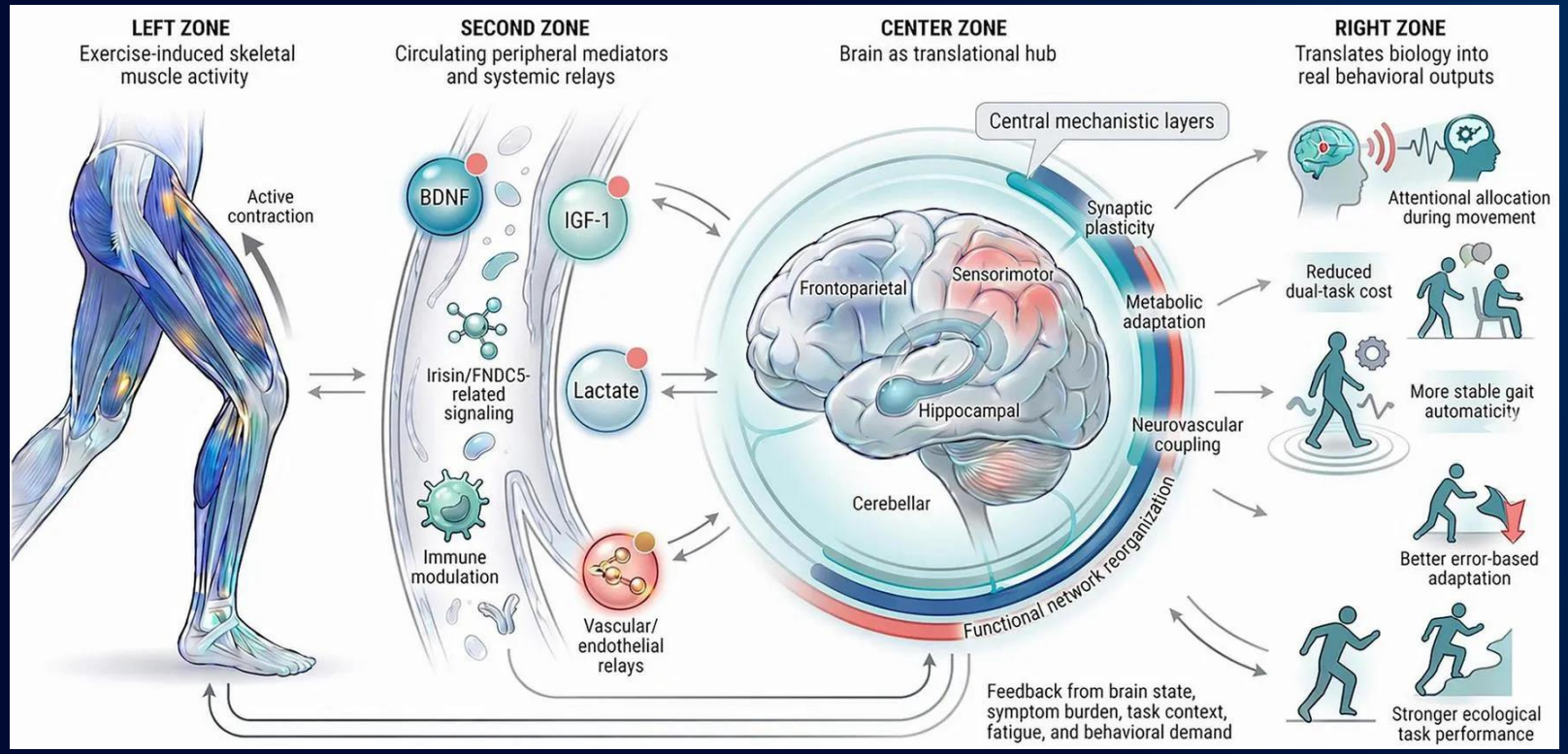
PRS Protocol Registration & Results System

Brief Title	NCT Number	Unique Protocol Id
Robotic Rehabilitation of the Upper Limb in Subacute Stroke	NCT06839482	266/IRE/24

Results Summary

Motor Recovery	• Better range of motion, greater improvement in upper limb motor function (FMA,BBT, ADL) • Reduced shoulder spasticity • Longer-lasting improvements: Functional gains at 6-months FU
Predictive Value of Kinematic Parameters	• Trajectory accuracy (e.g., trajectory error to target C) at baseline predicts strength at discharge • Lower baseline accuracy → lower motor recovery
Clinical Implications	• Electromechanical systems serve both as therapeutic and predictive tools • Support realistic goal setting and personalized rehabilitation plans
Consistency with Literature	• Motor synergies in stroke recovery (Dipietro et al., 2007) • Baseline motor impairment as outcome predictor (Coupar et al., 2012)

Integrated model of exercise-responsive cognitive-motor recovery.



frontiers in Psychology

TYPE Review
PUBLISHED 17 June 2026
DOI 10.3389/fpsyg.2026.1845070

Muscle and mind: rewiring cognitive-motor recovery through exercise-responsive neurophysiology in neurological populations

Andrea Calderone[1]*, Alessio Baricich[2,3], Sanaz Pournajaf[4,5], Fabrizio Sottile[1], Maria Grazia Maggio[1], Mirjam Bonanno[1], Rosaria De Luca[1], Francesco Ligato[1], Angelo Quartarone[1] and Rocco Salvatore Calabrò[1]

[1]IRCCS Centro Neurolesi Bonino Pulejo, Messina, Italy, [2]Department of Biomedical Sciences, Humanitas University, Milan, Italy, [3]IRCCS Humanitas Research Hospital, Milan, Italy, [4]Research Area in Neuromotor Rehabilitation and Rehabilitation Robotics, Department of Neuroscience, IRCSS San Raffaele Roma, Rome, Italy, [5]Department of Mental and Physical Health and Preventive Medicine, University of Campania 'Luigi Vanvitelli', Naples, Italy

"Exercise is not the endpoint of rehabilitation, but the biological gateway through which cognition and movement become function."

SRT Lab-Dessintay Overview

SRT is a guided self-rehabilitation platform for integrated cognitive–motor rehabilitation:

- Focused on upper limb recovery
- enables active, self-initiated training
- delivers high-intensity, goal-directed, cognitively embedded practice
- adaptable across different neurological conditions

SRT does not assist movement, but rather promotes active, goal-directed motor control through guided, self-initiated interaction.

SRT-Dessintay Mechanisms of Action

From movement to goal-directed action

It links perception, intention and action.

Promote engagement and autonomy

Drives engagement and supports autonomous training.

Real-Time Biofeedback and Visuomotor Integration

It shapes movement through continuous visual feedback, enabling real-time adaptation.

Cognitive-Motor Integration

It integrates motor execution with attention, precision and decision-making.

SRT Lab operationalizes the ICF model by bridging body functions, activity and participation through structured, goal-directed practice.

Our Clinical Experience

Stroke

Parkinson's Desease

Pediatrics

Case#1 Description

Diagnosis: Ischemic stroke

- Sex/Age: Male, 65 years
- Time since onset: > 6 months

Clinical and Functional Profile:

- Right hemiparesis;
- Bamford classification: PACI (posterior circulation)
- Montreal Cognitive Assessment (MOCA): 23/30
- Motricity Index (MI):
  - Upper limb (AS): 47/100
  - Lower limb (AI): 63/100
- Modified Barthel Index (mBI): 65/100

Main domains benefiting from SRT – integrated Stroke Rehabilitation

1
- Attention
- Working memory

2
- Executive functions
- Dual-task abilities

3
- Upper limb motor function

4
- Reaching

5
- Bilateral coordination

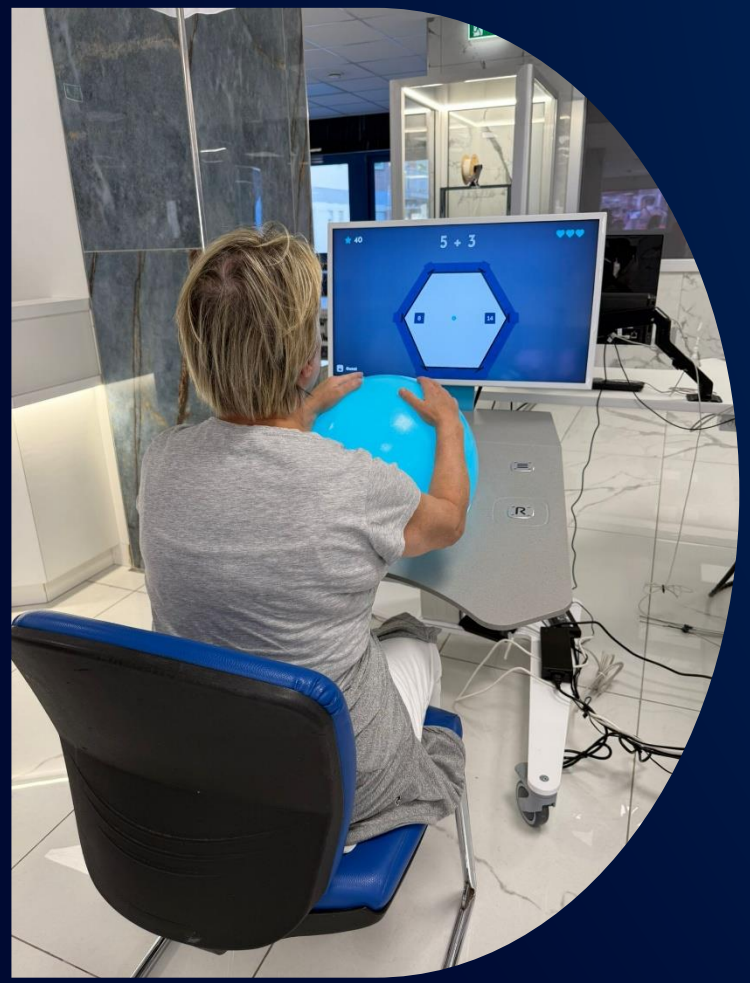
Case#2 Description

Diagnosis: Parkinson's Disease (PD)

- Sex/Age: Female, 61 years
- Disease duration: 8 years (onset: 2018)
-

Clinical and functional profile:

- Hoehn & Yahr stage: 2
- Cognitive status: MoCA: 26/30
- Predominant distal upper limb impairment
- Presence of resting tremor
- Modified Barthel Index (mBI): 70/100



Main domains benefiting

from SRT – integrated PD Rehabilitation

1. **Motor initiation**
2. **Cognitive set-shifting**
3. **Dual task**
4. **Attention**
5. **Processing speed**

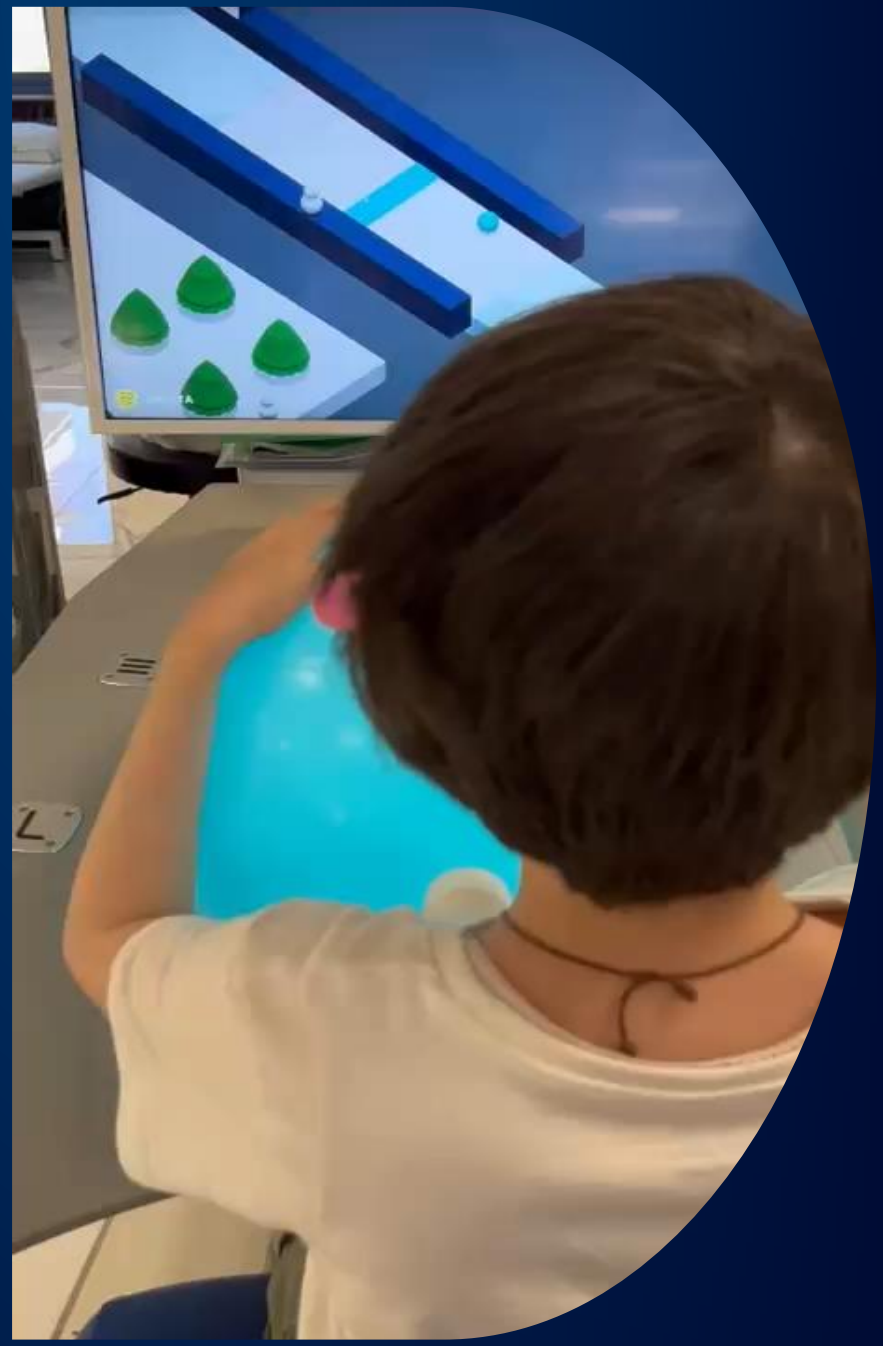
Case#3 Description

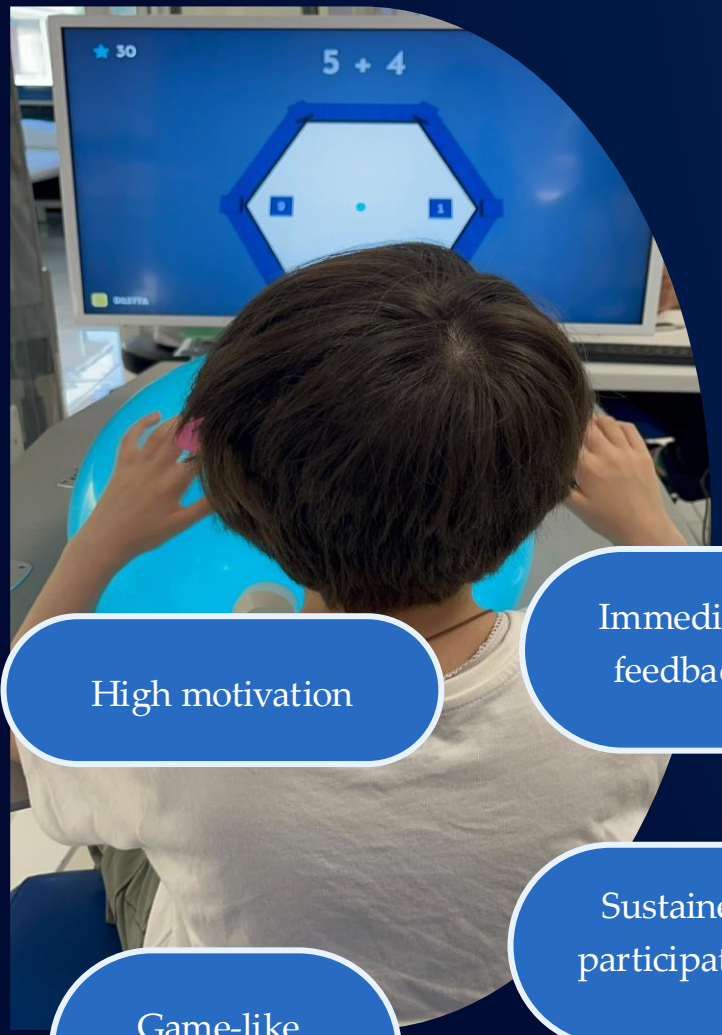
Diagnosis: Pediatric Neurodevelopmental Disorder
Intellectual disability associated with cerebellar vermis and hemispheric hypoplasia (Dandy–Walker variant)

- Sex/Age: Female, 9 years
- Clinical classification: DSM-5

Clinical and Functional Profile:

- Psychomotor developmental delay
- Cerebellar involvement affecting coordination and motor control
- DSM: 5
- Modified Barthel Index (mBI): 68/100





High motivation

Immediate feedback

Sustained participation

Game-like environment

Main domains benefiting from SRT – integrated Pediatric Rehabilitation

1 **Attention**

2 **Executive functions**

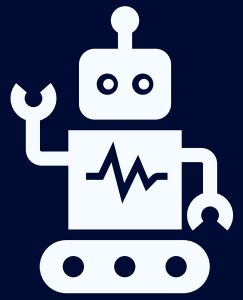
3 **Working memory**

4 **Inhibitory control**

5 **Cognitive flexibility**

A Vision for Rehabilitation

Rehabilitation must be patient-specific and time-sensitive



Intervention effectiveness depends on clinical profile and disease stage.

Neuroplasticity is shaped by active, goal-directed experience

Motor recovery emerges from cognitively engaged practice.

Functional outcomes depend on meaningful interaction

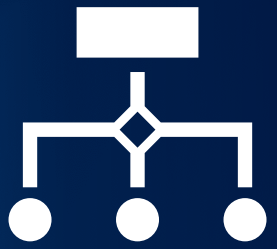
From motor performance to participation.

Conclusions & Future Prospects

High-intensity and task-specific training are essential for neuro-recovery but not enough.

SRT enables scalable, structured self-rehabilitation.

Next step: integrate technology-enabled therapy into standard care pathways through multicenter research networks.



Recovery does not emerge from intensity alone

It emerges from the interaction between biological readiness and cognitively meaningful action.

Future Developments & Collaborations

- Ongoing research initiatives on integrated cognitive–motor rehabilitation
- Focus on chronic neurological and neurodegenerative conditions
- Development of structured, scalable self-rehabilitation protocols
- Integration of physical and cognitive training paradigms

Jacques & Gloria Gossweiler Foundation

eWall eWallproject.eu

Ministero della Salute Scientific IRCCS Network

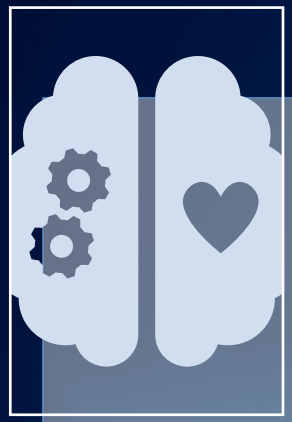
European Commission

esa European Space Agency

SmartCARE

Future Developments & Collaborations

Research Focus
- Integrated cognitive–motor + physical training
- Chronic neurological conditions
- Scalable rehab



Mechanisms of Interest
- Neurophysiological changes
- Cognitive–motor interaction
- Adaptive neuroplasticity

Digital Biomarkers
- Kinematic parameters
- Dual-task performance
- Predictive recovery indicators

Vision
- ICF-based framework
- Impairment → Function →Participation
- Personalized rehabilitation

Protocol under preparation for ethics committee submission

Thank you!

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Adj. Professor of Neurorehabilitation Methodology

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> Rehabilitation is not about isolated improvements it is about returning to life.

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