INTERNATIONAL REHABILITATION WORKSHOP

DESSINTEY SUMMER SCHOOL 2026

Saint-Étienne, France | June 23–24, 2026

Rebuilding Body Representation After Stroke

The Conditioned Mirror Training Protocol

Prof. Rocco Salvatore Calabrò, MD, PhD

Neurologist and Specialist in Clinical Sexology

S1 Senior Neurologist (Highest Specialist Qualification)

Coordinator, Research Line 1:
Neurorehabilitation – Technological Innovations in Rehabilitation

IRCCS Centro Neurolesi Bonino Pulejo, Messina, Italy

Expert in: Robotic Rehabilitation | Virtual Reality | Telemedicine | Neurorehabilitation

CENTRO NEUROLESI BONINO PULEJO IRCCS MESSINA

Dessintey

	BODY SCHEMA	BODY IMAGE	BODY REPRESENTATION
Definition	An **unconscious, dynamic sensorimotor representation** of the body's position, movement, and posture in space, used to guide actions.	A **conscious perception and evaluation of one's body**, including thoughts, beliefs, and emotions about appearance.	An **umbrella term** for all mental representations of the body, including both body schema and body image.
Level of awareness	Unconscious	Conscious	Both conscious & unconscious
Function	Guides movement and coordination	Shapes perception, attitudes, and feelings about the body	General understanding and experience of the body
Type of processing	Sensorimotor	Cognitive, emotional, perceptual	Combination of all processes
Flexibility	Highly dynamic and constantly updated	Relatively stable but can change	Broad and variable
Main role	Action-oriented (movement control)	Perception & self-evaluation	Integrative concept

Sattin D, et al. **An Overview of the Body Schema and Body Image: Theoretical Models, Methodological Settings and Pitfalls for Rehabilitation of Persons with Neurological Disorders**. Brain Sci. 2023

MOVEMENT CONTROL AND BODY REPRESENTATION

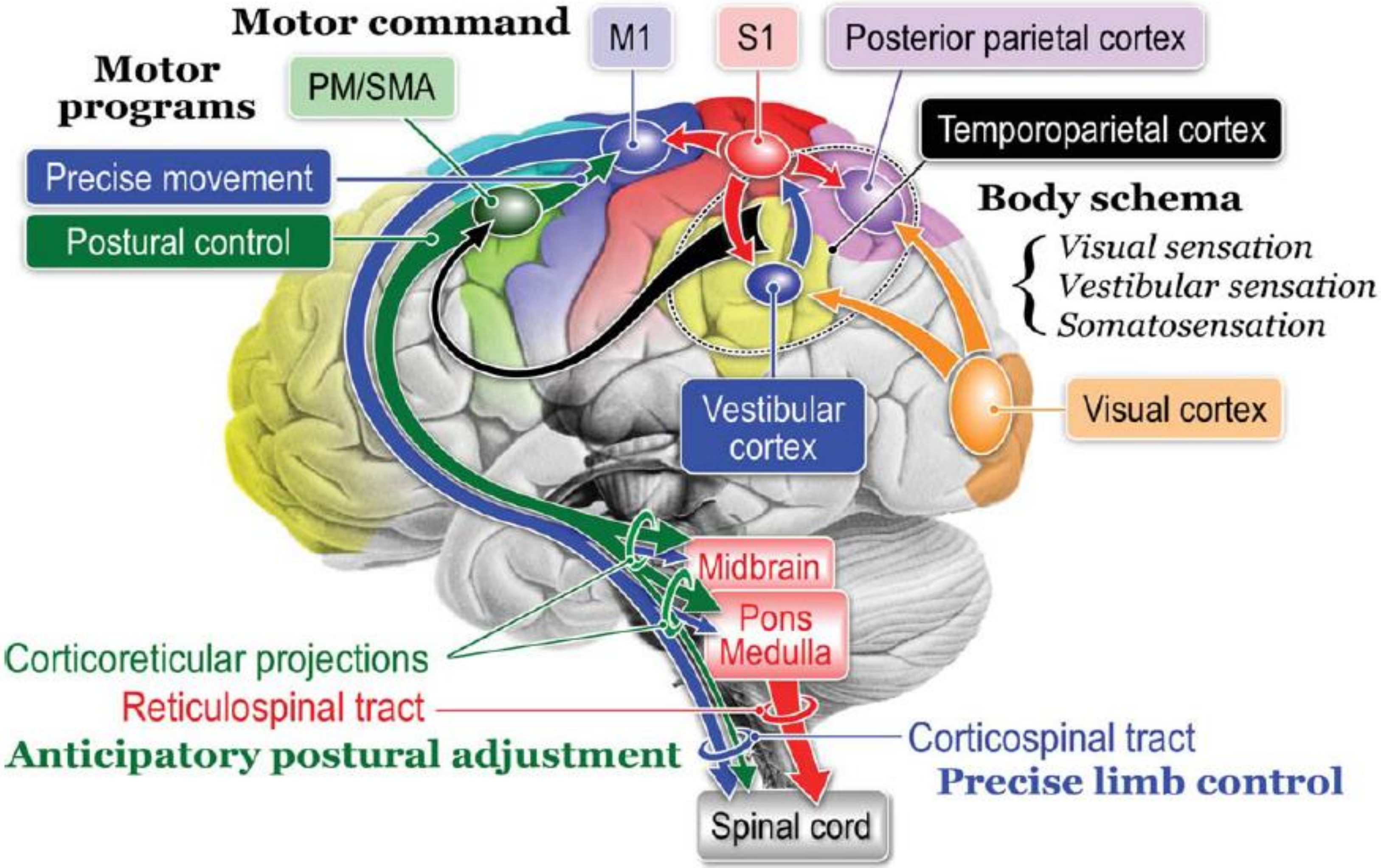


FIG. 4. Cortical mechanisms involved in movement control. Motor programs of precise movement and postural control are generated in the premotor area (PM) and the supplementary motor area (SMA). Descending signals from these areas to the brainstem by the corticoreticular projection may contribute to anticipatory postural adjustment by activating the reticulospinal tract. Motor command for precise limb control during locomotion is carried by the corticospinal tract arising from the primary motor cortex (M1). Somatosensory, vestibular, and visual sensations are integrated at the temporoparietal-posterior parietal cortices, where the body schema is generated and updated. This bodily information is transmitted to the PM/SMA and is utilized to generate motor programs. S1, primary sensory cortex.

Background

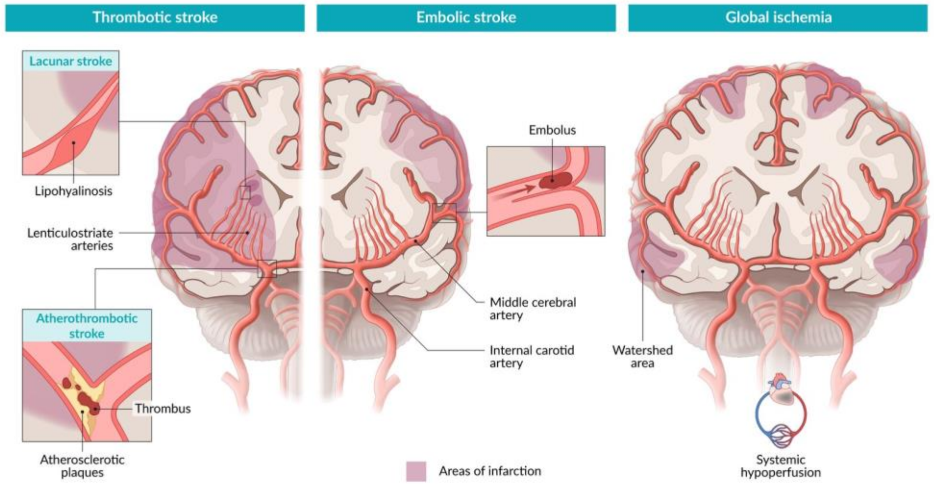
Body Representation After Stroke

Stroke **disrupts** the internal representation of the body and the sense of ownership of the affected limb.

Altered body representation contributes to **learned non-use** and limits motor recovery.

Restoring an accurate body representation is a **key target** for improving motor function and daily activities.

Rehabilitation strategies that engage sensorimotor networks can promote **neuroplasticity** and recovery.

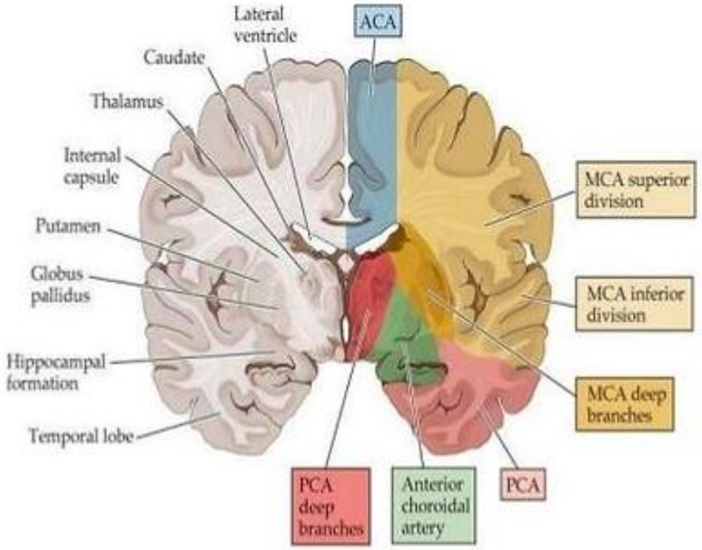


ALTERED BODY REPRESENTATION MAY LEAD TO:

- Impaired body ownership
- Altered motor planning
- Reduced motor imagery abilities
- Learned non-use of the affected limb

CLINICAL IMPLICATIONS

- Reduced functional recovery
- Impaired performance in activities of daily living
- Altered awareness of the affected limb



REHABILITATION GOAL

Restore the link between body representation and movement

Observation → Motor Imagery → Execution

MIRRORING AND BEYOND

IVS3 MIRROR FEEDBACK APPROACH

- Mirrored visual feedback of the unaffected limb
- Creates the illusion of normal movement
- Reduces learned non-use
- Provides a passive sensory experience

COMPLEX CLINICAL PRESENTATION

- Apraxia
- Altered body representation
- Impaired motor planning

CONDITIONED MIRROR TRAINING

OBSERVATION
(Action observation)

↓

MOTOR IMAGERY
(Internal simulation)

↓

PROGRESSIVE EXECUTION
(Graded motor activation)

↓

FUNCTIONAL ACTION
(Goal-directed performance)

	MIRROR FEEDBACK APPROACH	CONDITIONED MIRROR TRAINING
	Visual illusion	Active cognitive–motor engagement
	Observation only	Observation + motor imagery
	Passive processing	Goal-directed action
	Movement perception	Body representation reconstruction
	Short-term sensory effect	Long-term functional reorganization

CASE DESCRIPTION

Female, 65 years

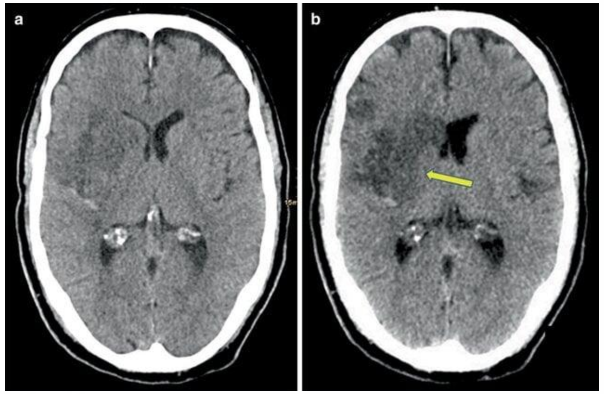
MEDICAL HISTORY

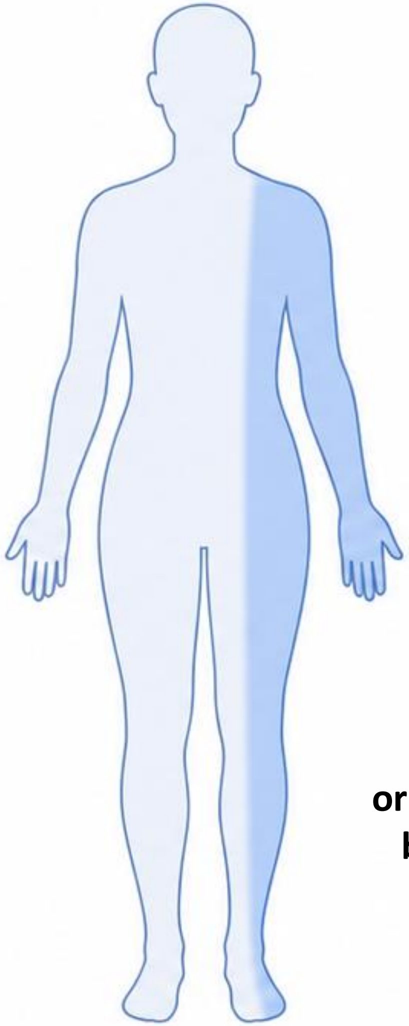
- Type II diabetes mellitus
- Arterial hypertension
- Left frontal extra-axial meningioma (neuroradiological follow-up)
- Previous vascular surgery (aorto-subclavian bypass and TEVAR)

DIAGNOSIS
Ischemic stroke of the middle cerebral artery thre month before our visit (october 2025)

MOTOR FEATURES

- Left-sided motor weakness
- Impaired upper-limb coordination
- Mild gait instability
- Retropulsion tendency





AFFECTED SIDE: LEFT

The patient was originally left-handed but was corrected

WHY THIS PATIENT?

Prominent alterations in body representation, praxis, visual processing and sensorimotor integration made her an ideal candidate for the Conditioned Mirror Training Protocol.

KEY NEUROPSYCHOLOGICAL FEATURES OF THE PATIENT

1	**ANOSOGNOSIA**	▪ Reduced awareness of neurological deficits. ▪ The patient may underestimate or fail to recognize functional impairments.
2	**IDEOMOTOR APRAXIA**	▪ Difficulty performing learned gestures despite preserved strength and comprehension. ▪ Reflects impaired transformation of intention into action.
3	**VISUAL PERCEPTUAL DEFICITS / AGNOSIA**	▪ Difficulty interpreting and recognizing visual information despite preserved visual acuity. ▪ May interfere with object recognition and interaction with the environment.
4	**PROSOPOAGNOSIA (FACE BLINDNESS)**	▪ Difficulty recognizing familiar faces despite normal vision and preserved memory for other information. ▪ Can affect social interactions and personal relationships.

WHY ARE THESE DEFICITS RELEVANT?

All these impairments involve disrupted links between:

PERCEPTION → BODY REPRESENTATION → ACTION

making the patient an ideal candidate for the **Conditioned Mirror Training Protocol.**

Coslett HB. Apraxia, Neglect, and Agnosia. Continuum (Minneap Minn). 2018

Kim DC, Park J, Kim MW. Systematic Review of the Treatment of Anosognosia for Hemiplegia in Stroke. Brain Sci. 2025

OBJECTIVES

PRIMARY OBJECTIVE

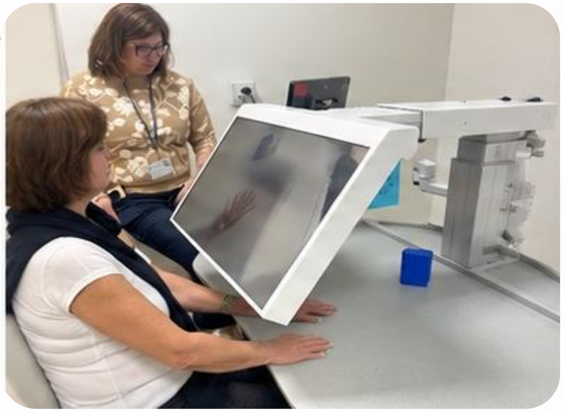
To restore the link between body representation and movement through **immersive visual stimulation** and progressive sensorimotor training.

SECONDARY OBJECTIVES

- Enhance motor imagery abilities
- Promote sensorimotor integration
- Reduce learned non-use of the affected upper limb
- Improve praxis and action planning
- Increase self-efficacy and engagement during movement

CLINICAL HYPOTHESIS

Reinforcing the connection between motor **intention, body representation and action** may facilitate functional recovery after stroke.



Motor Intention ⟷ Body Representation ⟷ Movement

↓

IVS3

+

Motor Imagery

+

Progressive Motor Execution

↓

Improved Attention	Enhanced Praxis	Better Body Awareness	Improved Motor Recovery

TRAINING STRUCTURE

Conditioned Mirror Training Protocol

5	15	3	45
WEEKS	SESSIONS	SESSIONS / WEEK	MIN / SESSION
Program duration	Total sessions	Training frequency	Session duration

ASSESSMENTS

T0	T1	T2
BASELINE	AFTER 7 SESSIONS	END OF PROGRAM
Full assessment (clinical + EEG)	EEG ONLY	Full assessment (clinical + EEG)

ASSESSMENT BATTERY

Cognitive functions, praxies, body representation, motor imagery, motor performance, mood, pain and fatigue.

ASSESSMENT BATTERY

1. COGNITION AND PRAXIS

- Montreal Cognitive Assessment (MoCA)
- Attentive Matrices Test
- Trail Making Test B (TMT-B)
- Trail Making Test B–A (TMT B–A)
- De Renzi Praxis Test
- Rey Figure Test – Immediate Recall
- Rey Figure Test – Delayed Recall

2. BODY REPRESENTATION

- Body Perception Questionnaire (BPQ) – Supra Diaphragmatic Symptoms
- Body Perception Questionnaire (BPQ) – Sub Diaphragmatic Symptoms
- Body Perception Questionnaire (BPQ) – Autonomic Symptoms
- Motor Imagery Measure for Adults (MIMA) – B

3. MOTIVATION AND WELL-BEING

- Beck Depression Inventory (BDI)
- State Trait Anxiety Inventory (STAI-Y1)
- State Trait Anxiety Inventory (STAI-Y2)

4. MOTOR ASSESSMENT

MOTOR RECOVERY

- FMA-UE-A-D (Upper Limb Movement)
- Motricity Index (Left Upper Limb)

SENSORY FUNCTION

- Semmes-Weinstein Sensory Test
- FMA-UE Sensation

PAIN AND JOINT FUNCTION

- FMA-UE Joint Pain
- Passive Joint Movement

MUSCLE TONE

- Modified Ashworth Scale

5. ASSESSMENT TIMEPOINTS

T0

Baseline (pre-treatment)

- Full clinical assessment (all domains 1–4)
- EEG recording

T1

Mid-treatment (before session 7)

- EEG recording only

T2

End of treatment (post-treatment, before last session)

- Full clinical assessment (all domains 1–4)
- EEG recording

YH, Choi YA. **Montreal Cognitive Assessment and Frontal Assessment Battery test as a predictor of performance of unaffected hand function after subcortical stroke**. Int J Rehabil Res. 2021

LONGITUDINAL EEG ASSESSMENT

High-Density EEG (256 Channels)

Neurophysiological evaluations were performed at three predefined timepoints throughout the rehabilitation program.

T0
Baseline Assessment
(before Session 1)

T1
Mid-Treatment Assessment
(before Session 7)

T2
Post-Treatment Assessment
(before Final Session)

EEG RECORDING CONDITIONS

1. Resting State	2. Hand Opening	3. Finger Extension	4. Reaching and Grasping Tasks (Book and Bottle Tasks)

NEUROPHYSIOLOGICAL OUTCOMES

- Source localization of sensorimotor activity
- Functional connectivity analysis of cortical networks
- Monitoring of cortical reorganization during recovery

256-CHANNEL HD-EEG SYSTEM

- High-density scalp recording
- Whole-head cortical coverage
- High spatial resolution
- Source localization analysis
- Functional connectivity assessment
- Longitudinal monitoring of neuroplasticity

CORE THERAPEUTIC PROCEDURE

The Conditioned Mirror Training Sequence

1 ACTION OBSERVATION

The patient observes the mirrored image of the unaffected limb and attributes the movement to the affected limb.

2 MOTOR IMAGERY

While observing the mirrored movement, the patient mentally rehearses the same action.

3 MOVEMENT EXECUTION WITH VISUAL FEEDBACK

The patient attempts to perform the movement while observing the mirrored visual feedback.

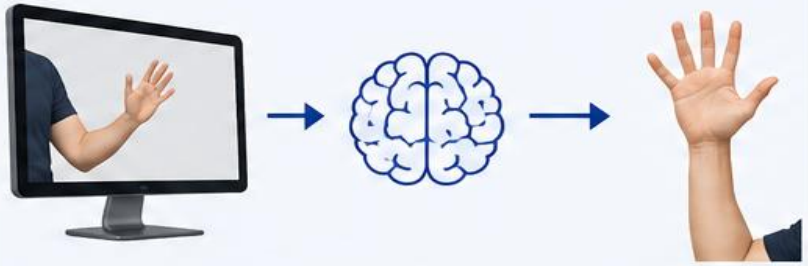
REPEAT 3 TIMES

---

4 AUTONOMOUS EXECUTION

The movement is performed without visual feedback to consolidate the internal link between motor intention, body representation and action.

PROGRESSIVE COUPLING



SEE (Observation) → **THINK** (Imagery) → **DO** (Execution)

THEN

AUTONOMOUS EXECUTION

(Without Visual Feedback)

KEY CONCEPT

The protocol progressively couples perception, imagination and execution before removing visual feedback, promoting sensorimotor integration and body representation updating.

TRAINED MOVEMENTS

Upper-Limb Training Program

The training focused on key upper-limb movements to improve motor control, dexterity and functional use of the affected hand.

1 Shoulder Rotation and Arm Opening

Opening the hand while performing shoulder rotation.

2 Finger Extension

Selective finger opening and dissociation.

3 Thumb Opposition

Thumb flexion–extension and opposition movements.

4 Spiral Drawing

Clockwise spiral tracing with progressive precision demands.

5 Reaching and Grasping

Reaching, grasping and object manipulation (e.g., book, bottle and other functional objects).

PROGRESSIVE DIFFICULTY ADJUSTMENT | Task complexity was gradually increased by reducing object size, increasing movement precision and introducing more functionally demanding actions.

MULTIDISCIPLINARY REHABILITATION TEAM

Integrating clinical, neurophysiological and technological expertise

TRAINING
(Neuropsychology + Physiotherapy)

1 NEUROPSYCHOLOGY

- Neuropsychological assessment
- Body representation evaluation (specific tests and questionnaires)
- Definition of personalized goals
- Motor imagery training
- Motivational interviewing and education

Goal: improve body awareness and readiness for motor intervention

2 PHYSIOTHERAPY

- IVS3 intervention (observation + motor imagery + execution)
- Progression from simple to complex tasks
- Bilateral and unilateral training
- Functional tasks and transfer to daily activities
- Continuous monitoring and adaptation of the training

Goal: improve motor control, functionality and independence

→

EEG ANALYSIS & TECHNICAL SUPPORT
(Neurophysiology + Engineering)

3 NEUROPHYSIOLOGY

- High-density EEG acquisition (T0, T1, T2)
- Source localization analysis
- Functional connectivity assessment
- Neuroplasticity monitoring and changes over time

Goal: identify and monitor neurofunctional changes associated with motor recovery

4 ENGINEERING & TECHNICAL SUPPORT

- EEG signal pre-processing and management
- Data integration and organization
- Quantitative and statistical analysis
- Technological support and data quality control

Goal: ensure data quality, reliable analysis and technical support to the team

KEY MESSAGE

The strength of this protocol lies in the integration of **neuropsychology** and **physiotherapy** as core clinical drivers for training design and delivery, and **neurophysiology** for EEG analysis, supported by **engineering** for data management and technical support, all working together within a personalized rehabilitation pathway.

From body representation to functional recovery

MOTOR OUTCOMES: T0–T2

Clinically meaningful improvements in upper-limb function

1. MOTOR RECOVERY

- FMA-UE A–D (Upper Limb Movement)

31 → 57

+26 points

- Motricity Index (Left Upper Limb)

70 → 100

+30 points

2. SENSORY FUNCTION

- Semmes–Weinstein Sensory Test

Grade 4 → Grade 5

- FMA-UE Sensation

12 → 12

(stable)

3. PAIN AND JOINT FUNCTION

- FMA-UE Joint Pain

10 → 20

+10 points

- Passive Joint Movement

20 → 20

(stable)

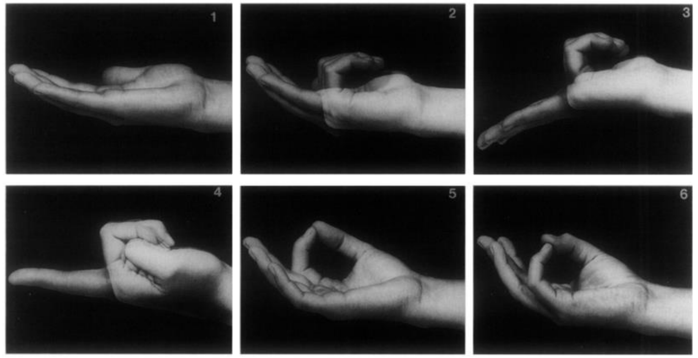
4. MUSCLE TONE

- Modified Ashworth Scale

1 → 1

(stable)

Substantial improvements were observed in **voluntary upper-limb movement**, motor strength, sensory discrimination and pain, while muscle tone and passive joint mobility remained stable.



RESULTS T0–T2: IMPROVEMENTS AND STABILITY

Only improvements and stability – Real patient (case report)

IMPROVEMENT
STABILITY

1. COGNITION AND PRAXIS

Montreal Cognitive Assessment (MoCA)	21 → 23	(+2)
Attentive Matrices Test	20 → 23.75	(+3.75)
Trail Making Test B (TMT-B)	137 → 137	(=)
Trail Making Test B-A (TMT B-A)	25 → 3	(–22)
De Renzi Praxis Test	61 → 64	(+3)
Rey Figure Test – Immediate Recall	5.7 → 8.7	(+3)
Rey Figure Test – Delayed Recall	8.2 → 11.7	(+3.5)

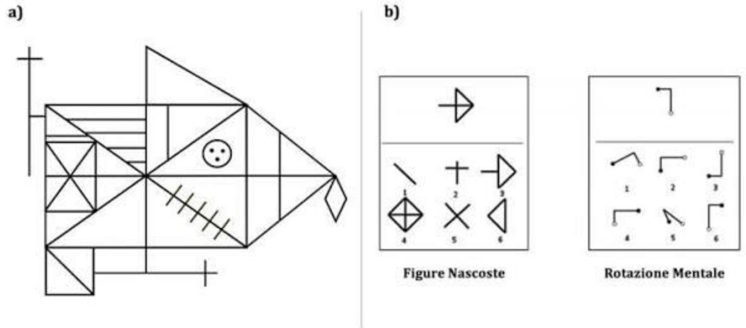
2. BODY REPRESENTATION

Body Perception Questionnaire (BPQ) – Supra Diaphragmatic Symptoms	15 → 12	(–3)
Body Perception Questionnaire (BPQ) – Sub Diaphragmatic Symptoms	6 → 6	(=)
Body Perception Questionnaire (BPQ) – Autonomic Symptoms	20 → 20	(=)
Motor Imagery Measure for Adults (MIMA) – B	20 → 25	(+5)

3. MOTIVATION AND WELL-BEING

Beck Depression Inventory (BDI)	9 → 10	(stable)
State Trait Anxiety Inventory (STAI-Y1)	43 → 42	(stable)
State Trait Anxiety Inventory (STAI-Y2)	43 → 42	(stable)

Only tests showing improvement or stability are reported.
Tests not reported do not show positive changes or have worsened.



SUMMARY: Significant improvements were observed in attention, executive functions, praxis, and visual memory.
Stability in anxiety, mood, and several aspects of body representation.

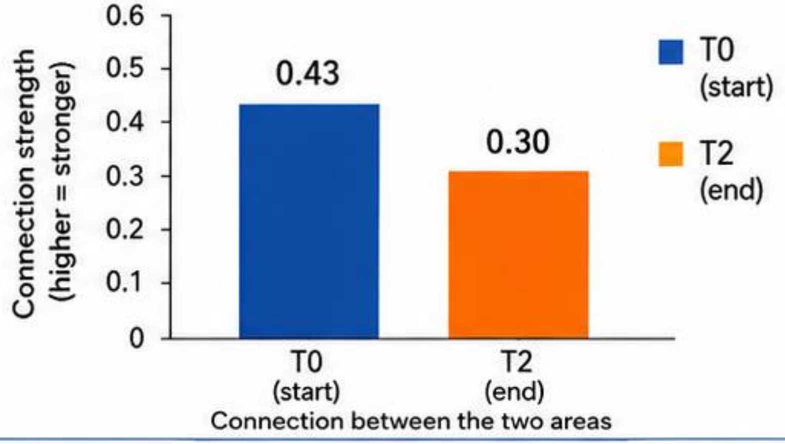
FUNCTIONAL CONNECTIVITY (RESTING STATE)

WHAT WE FOUND	WHAT IT MEANS
↓ **Frontal–Occipital Connectivity (Beta)**	Reduced compensatory activity in the frontal part of the brain
↑ **Temporal–Occipital Connectivity (Beta/Gamma)**	Better integration between visual areas and movement
= **Stable Posterior Connectivity at T2**	Consolidation of brain changes over time

Left Frontal – Left Occipital (Beta Band)

↓ The connection decreases from T0 to T2

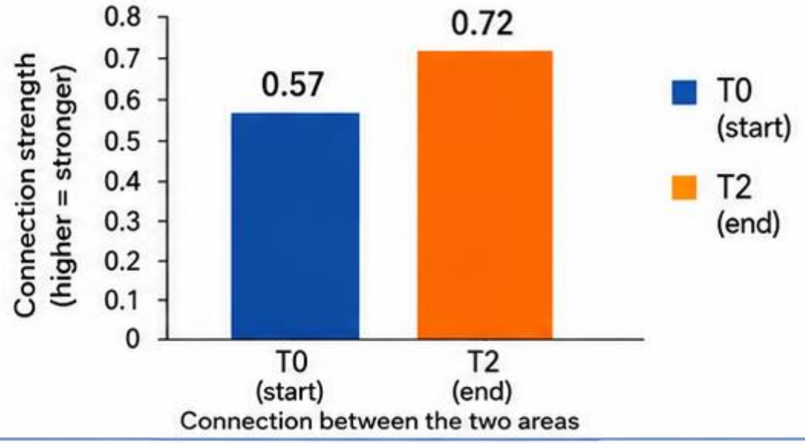
LESS FRONTAL COMPENSATION



Right Temporal – Right Occipital (Beta/Gamma Bands)

↑ The connection increases from T0 to T2

BETTER INTEGRATION



WHAT THIS MEANS FOR RECOVERY

Recovery is related to a **better organization** of brain networks: activity shifts from frontal “compensatory” areas to posterior areas, involved in body awareness, movement and vision.

KEY MESSAGE

It’s not about having more brain activity, but about **where** and **how** different areas work together.

These positive changes in brain connections are associated with better functional recovery.

DISCUSSION

Beyond Motor Recovery: Rebuilding the Perception–Action Loop

1 OBSERVATION

Visual illusion increased attention.

Observation focused on the affected limb.

FOCUS

2 MOTOR IMAGERY

Motor imagery linked observation to movement.

Strengthened intention–action coupling.

INTENTION

3 EXECUTION

Repeated practice reinforced perception–action connections.

Better integration of visual and motor information.

INTEGRATION

4 BODY REPRESENTATION

Improved body awareness of the affected limb.

Reorganization of the body schema.

Key element for functional recovery.

AWARENESS

5 FUNCTIONAL RECOVERY

Improvements in praxis and daily activities.

Benefits extend beyond motor domain.

IMPACT

Better results if IVS3 is part of structured and valideted protocols

KEY MESSAGE

Recovery was not driven by mirroring alone.

The combination of observation, motor imagery, and active execution promoted body representation reconstruction and functional recovery.


Thank you
For your
Attention