Intensive Visual Simulation (IVS) and its core principles

Moving Minds
Empowering Bodies

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Introduction

The field of rehabilitation is constantly evolving, driven by major technological innovations that redefine patient care standards. These developments, range from robotic devices to immersive stimulation techniques that offer new perspectives in maximizing functional and cognitive capacities by improving patients' quality of life.

Among these innovations, the IVS technology (Intensive Visual Stimulation) stands out for its ability to activate complex cognitive and neurophysiological mechanisms that facilitate motor recovery. However, adopting these devices into clinical practice requires a scientifically grounded approach.

This document aims at:

- Providing an overview of the fundamental principles of IVS on motor aspects and cognition;
- Exploring the implementation of IVS into rehabilitation through concrete examples and scientific references.

It is intended for healthcare professionals, researchers, and therapists who wish to gain a deeper understanding of IVS and how it can be integrated into various clinical practices. We hope this exploration will help to guide the optimal, personalized, and ethical use of this technology.

Body Perception and Awareness

Perception is a complex cognitive operation that allows humans to reconstruct their surrounding space based on the sensory inputs. Vision is the dominant sens for humans, that relies on sight for building spatial awareness and guide all actions. Directed movement towards a goal requires the ability to extract relevant environmental information.

Body awareness is a key component of motor rehabilitation. It includes perception of body limits, spatial positioning, and recognition of sensations associated with movements.

These two elements are crucial in post-stroke rehabilitation, where patients often show global and/or body perception disorders, like hemineglect and/or body schema impairments.

> “Seeing a movement is almost like doing it.”
>
> **Pr. Pascal GIRAUX**
> Physical Medicine & Rehabilitation, CHU Saint-Étienne (FR)

The relevance of Body Awareness in rehabilitation

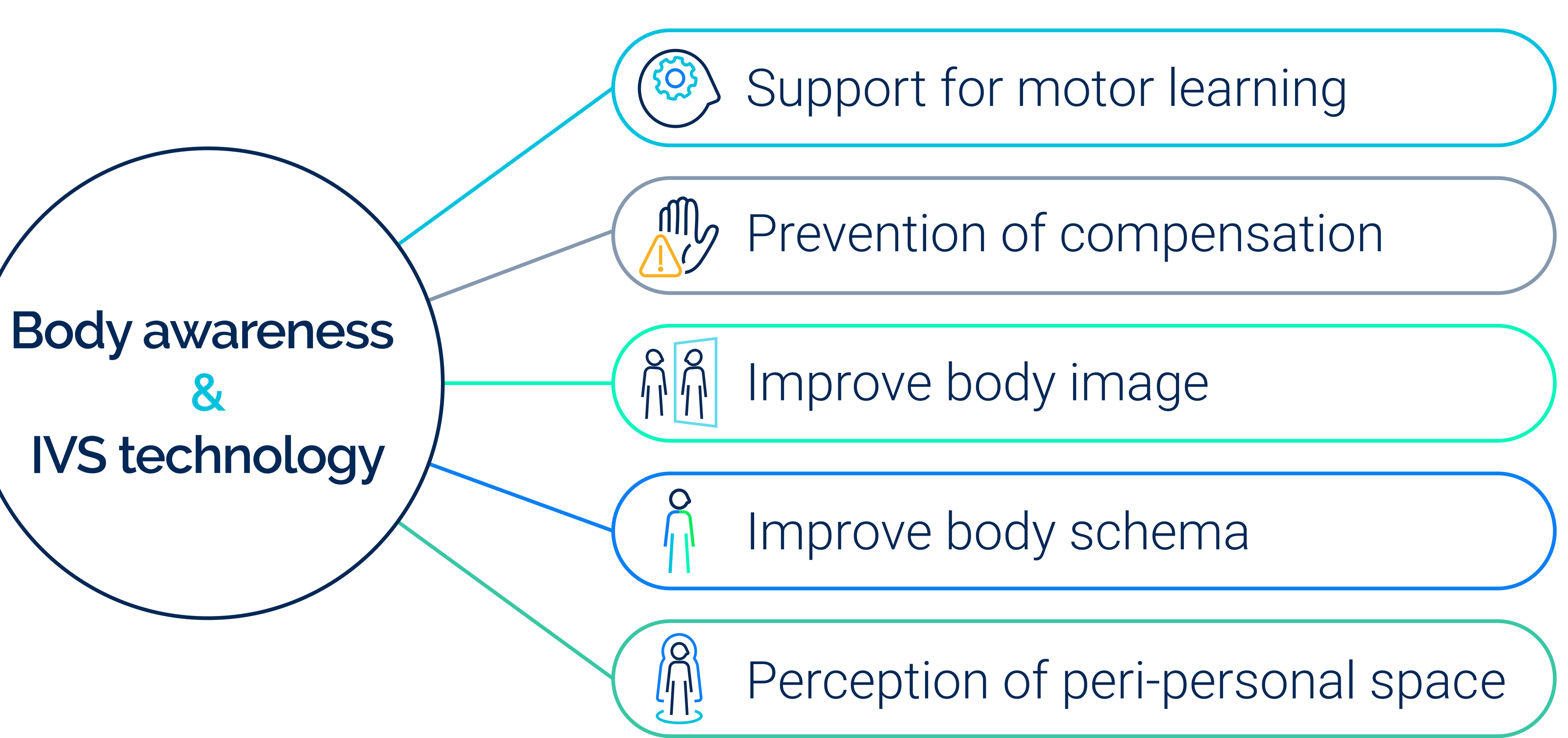
An enhanced body awareness allows:

- **Prevention of detrimental compensatory behaviors**
  Improved body perception encourages motor activity and reduces the likelihood of maladaptive compensations.
- **Motor learning support**
  A precise representation of the body is essential for coordinating complex movements and for the progressive motor skills’ automation.

Contribution of the IVS technology

IVS provides an immersive and realistic experience. It stimulates the patient’s:

- **Body image**
  By directing the attention to the affected limb while minimizing distractions.
- **Body schema**
  By reinforcing the mental representations of possible movements, motor abilities, and activities of daily living.
- **Peripersonal space**
  By re-establishing interaction capacities with objects in the patient’s immediate environment through involvement of the affected limb.



Body awareness is a key component of motor rehabilitation, in neurology as well as orthopedics. The integration of new technologies such as IVS offers an innovative solution to further enhance this aspect for patients who undergo (motor) rehabilitation.

Practical applications: Clinical example

This case involves a post-stroke survivor with severe hemi spatial neglect:

1. Familiarization with IVS interface
   The patient observes the simulated movements of the affected limb, centered on the screen to facilitate perception.
2. Guided gaze orientation
   The patient follows the hand movements that cross the midline to engage the exploration of the neglected hemispace.
3. Active reinforcement
   The patient attempts to synchronize the real movements with those projected on the screen.
4. Progression to functional tasks
   Reaching and grasping the objects in an enriched environment with or without disturbances.

Expected outcomes should include improved visual exploration of the neglected field, enhanced body awareness and more voluntary use of the neglected hand that lead to an overall reduction of the asymmetries in daily activities.

Future perspectives

Literature[1] has already demonstrated the effectiveness of mirror therapy and mental imagery techniques in promoting motor recovery and body awareness after stroke. Based on these foundations, Pr Stein and Dr Stilling (from NewYork-Presbyterian Hospital-Columbia University and Cornell Medicine) aim at going further by exploring how IVS technology — through immersive and interactive visual feedback — can not only amplify these benefits, but also specifically address the challenges of hemispatial neglect by reinforcing spatial attention and body representation on the affected side.

1: Thieme, H., Morkisch, N., Mehrholz, J., Pohl, M., Behrens, J., Borgetto, B., & Dohle, C. (2018). Mirror therapy for improving motor function after stroke. Cochrane Database of Systematic Reviews. https://doi.org/10.1002/14651858.CD008449.pub3

Action Planning and Praxis

Every movement is goal-oriented and requires a long and precise preparation, especially in daily activities or complex tasks.

It is therefore important to define the plan of action plan before carrying it out, to determine the most efficient way of achieving the goal comparing energy expenditure and probability of success.

IVS is particularly suited for neurological conditions and other disorders affecting praxis functions and cognitive-motor abilities, such as executive function impairments, memory deficits, and dual-task capacities.

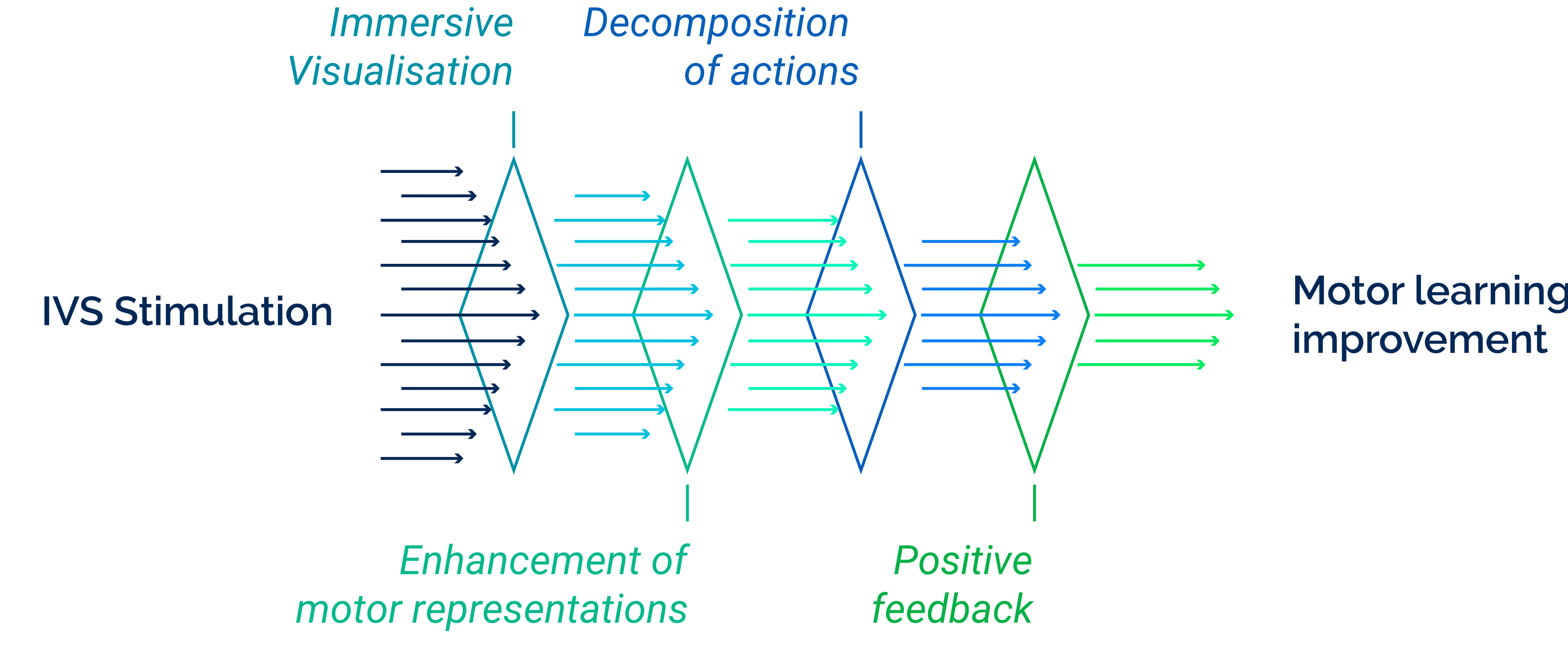
> "The problem is not repeating the movement but planning what needs to be done.
> It's not a matter of muscle strength;
> it's about body control."

Dr. Franco MOLTENI
Clinical Director - Villa Beretta
Rehabilitation Center, Italy

Contribution of the IVS Technology

IVS directly stimulates and improves praxis functions by:

- **Immersive visualization of movements**
  Patients observe precise representations of the target movements that enhance their imitation and reproduction abilities.
- **Enriching motor representations**
  Dynamic visual stimuli help to expand the motor memory "library".
- **Supporting motor learning**
  Especially in acute phases, IVS breaks down the complex actions into simpler components, making them easier to assimilate. Positive feedback further facilitates learning and consolidation of motor learning.



Action planning and praxis functions improvement thanks to IVS

Practical applications: Clinical example

In this case of ideomotor apraxia, a patient struggles to perform simple tasks like grasping and using a glass:

1. **Observation**
   The patient watches a correctly executed movement in slow motion.
2. **Guided imitation**
   With visual feedback, the patient attempts to replicate the movement (without an actual object behind the screen).
3. **Consolidation**
   At the end of the session, the patient performs the gesture again, observing their own action in real-time.

Studies (e.g., **Pazzaglia & Galli, 2019**[2]) indicate that visuomotor integration errors are common in apraxia. Action observation combined with imitation is a promising approach for restoring praxis functions. These perspectives highlight the impact of neurorehabilitation on brain repair that follow the precise strengthening of perceptual-motor coupling.

Future perspectives

Further research will explore the effectiveness of IVS to resolve **ideomotor apraxia** and provide adapted training protocols and their evaluations to identify responder and non-responder profiles.

2: Pazzaglia, M., & Galli, G. (2019). Action Observation for Neurorehabilitation in Apraxia. Frontiers in Neurology, 10. https://doi.org/10.3389/fneur.2019.00309

Motor control and abnormal contractions

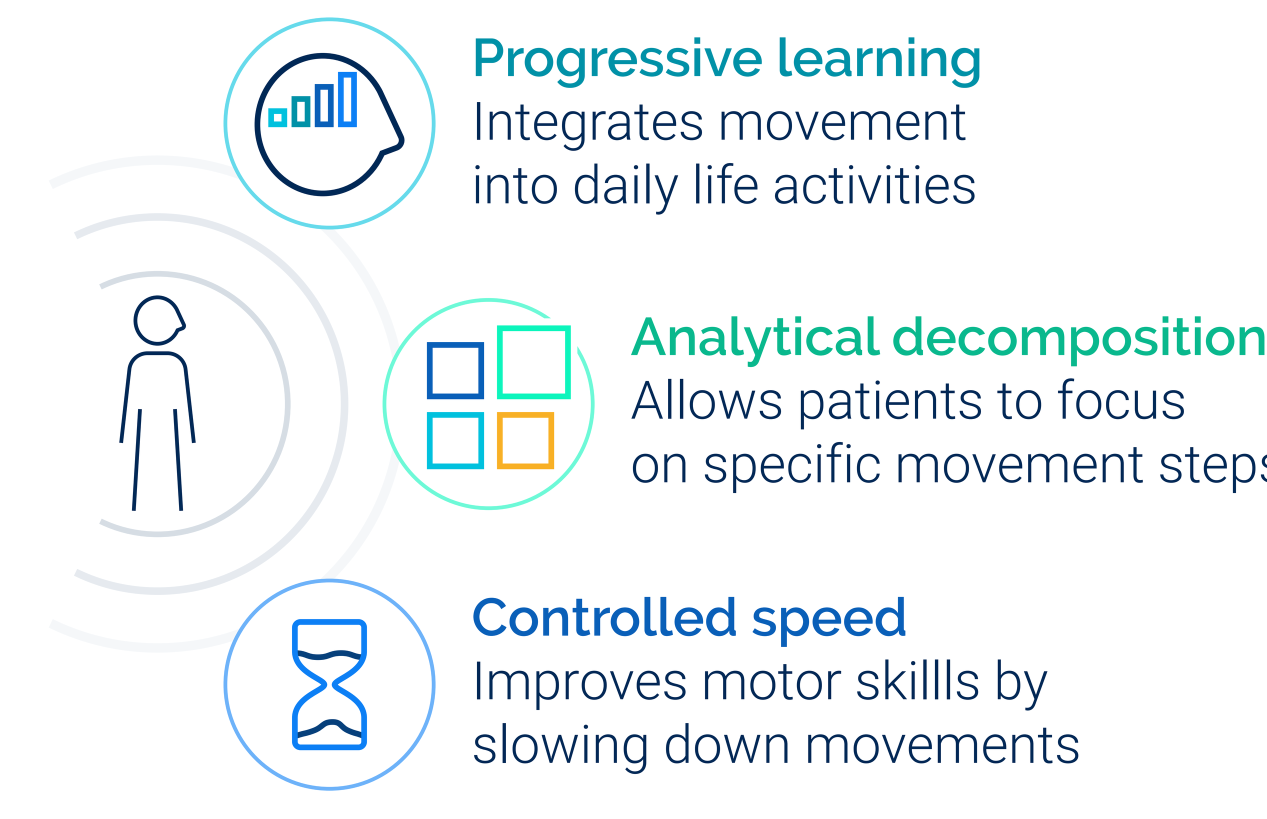
Motor control encompasses all processes within the nervous system that regulate movement.

To encourage motor initiation and correct muscle activation, or at the end of recovery to improve dexterity and intersegmental coordination, or as part of a dystonia and co-contractions reduction, rehabilitation must offer specific and gradual interventions.

Contribution of the IVS technology

Intensive Visual Simulation (IVS) provides an innovative solution that allows:

- **Analytical decomposition of movements**
  Real-time visual feedback that helps patients to isolate movement phases and refine their motor activation.
- **Controlled execution speed**
  Slowing down a movement enhances motor selection and reduces involuntary synergy patterns.
- **Fine motor selection and progressive functional learning**
  Repetitive exercises help integrate movement patterns by making them smoother and more functional (daily life activities).



IVS benefits

Practical applications: Clinical example

This case is a **post-stroke survivor with severe wrist and finger flexor dystonia:**

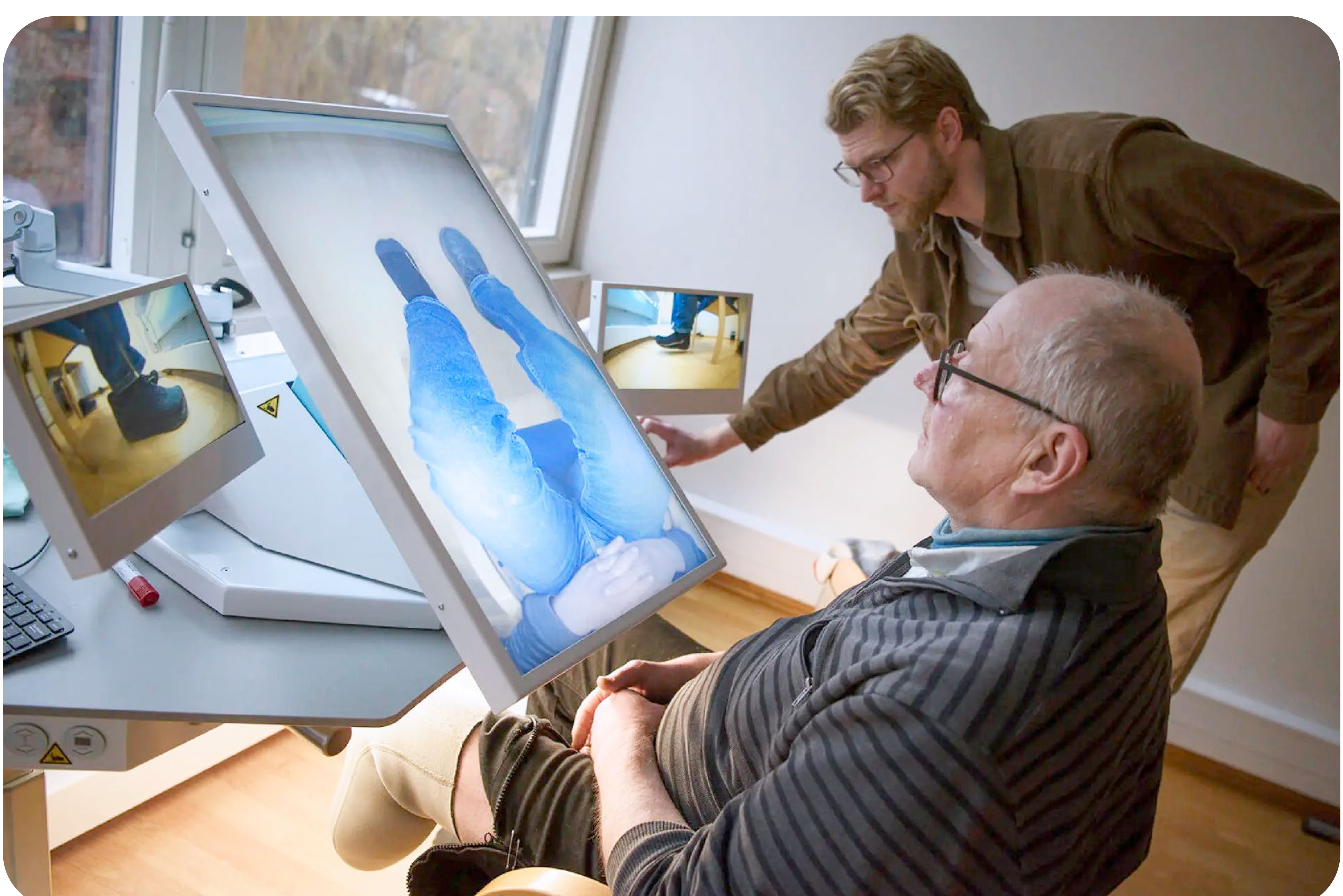
1. Observation
   Watching progressive finger/wrist extension movements in order to build body awareness and imagined representations of the movements.
2. Limited participation
   Attempting slight initiation of extension without an excessive effort in order to prevent flexion coactivation. Look for the right motor impulses.
3. Active participation
   Gradually producing the complete movement with minimal force and/or compensations.
4. Functional consolidation
   Post-session attempts to maintain relaxation and movement extension and also to raise the awareness of movement performance.

Observations indicate a **gradual reduction in resting tone (measured via Ashworth scale)** and improved fluidity in functional tasks.

Innovation and perspectives

Molteni et al., 2025[3] explored the effect of IVS therapy on Heart Rate Variability (HRV) and cognitive flexibility.
The authors demonstrate that focusing patients' attention on movement and performing a simulation of movement increases the para-sympathetic system. This activation may help patients to reduce the global tonus and dystonia and abnormal muscular activities.
Moreover, the usage of **non-invasive neuromodulations** to further improve the muscular selection may speed up the functional recovery processes.

3: Penati, R., Robustelli, A., Gasperini, G., Specchia, A., Paleari, V., Guanziroli, E., & Molteni, F. (2025). Heart Rate Variability as a Possible Biomarker of Cognitive-Motor Integration in Post-Stroke Patients. Advances in Rehabilitation Science and Practice, 14, 27536351251335133. https://doi.org/10.1177/27536351251335133



Sensorimotor Cortical Activation

IVS can emulate movement and create specific brain activation.

Movement observation activates motor and pre-motor areas as well as others key areas that are involved in movement production, even in the absence of physical movements.

Mental representation techniques offer a potential to activate sensorimotor networks, facilitated by action observation, motor imagery, and active execution of movements. This activation is essential to enhance neuroplasticity and functional recovery for many neurological pathologies or chronic pains.

Contribution of the IVS technology

The **Intensive Visual Stimulation (IVS)** technology enables activation by the recruitment of the fronto-parietal areas specific to the observed hand and contralateral to the focused limb focus.
The transition from a passive motor observation to an active motor imagery and to a final execution attempt demonstrates the gradual increase of cor-tical activity. This progressive modulation establishes a direct link between motor engagement level, cortical recruitment, and clinical rehabilitation goals.

Moreover, the presence of positive visual feedback reduces the perception of failure and error detection, reinforces brain plasticity and learning mechanisms. These activation models are both observed for the upper and the lower limbs.

Neurophysiological mechanisms

Recent studies (2024-2025) by Bonnal et al.[4] and Adham et al.[5] which use IVS demonstrate:

- Action Observation: Significant cortical activations occur even when a movement is simply observed without its physical execution. Additionally, a first-person perspective and the sense of ownership is induced through the IVS to improve cortical activation.
- Motor Imagery with visual support: Imagine a movement while simultaneously observing it enhances cortical activity. The complementary nature of both techniques leads to a reinforced cortical stimulation.
- Movement execution: The measured cortical activations in both healthy individuals and patients are significantly enhanced while attempting or executing the movement. The intensity of the cortical activation is not linked to the mechanical execution but rather to the attentional, cognitive, and intentional processes associated with movement production.

These activation patterns are observed in both the upper and the lower limbs.

Furthermore, these studies have measured the **Beta rebound phenome-non** via EEG after a movement execution.
This physiological marker corresponds to a post-movement validation (comparison between the previous motor plan and the real execution outcomes) and serves as a **positive marker of (motor) learning and brain plasticity**.
The presence of positive visual feedback minimizes the perception of failure by reinforcing the Beta rebound, brain plasticity and **motor learning**.

4: Bonnal, J., Ozsancak, C., Prieur, F., & Auzou, P. (2024). Video mirror feedback induces more extensive brain activation compared to the mirror box: An fNIRS study in healthy adults. Journal of NeuroEngineering and Rehabilitation, 21(1), 78. https://doi.org/10.1186/s12984-024-01374-1 | 5: Adham, A., Le, B. T., Bonnal, J., Bessaguet, H., Ojardias, E., Giraux, P., & Auzou, P. (2024). Neural basis of lower-limb visual feedback therapy: An EEG study in healthy subjects. Journal of NeuroEngineering and Rehabilitation, 21(1), 114. https://doi.org/10.1186/s12984-024-01408-8

Practical application: Clinical example

This case is a **severe post-stroke patient with left-sided hemiplegia who is admitted to rehabilitation**:

1. Failure and reduced participation: The patient perceives difficulty in moving the left hand by gradually reducing movement attempts, thus lowering cortical activity in the affected hemisphere and developing compensatory strategies.
2. Observation and habituation: The patient watches simulated movements of the affected limb by using IVS. It allows initial habituation and gradual activation of the perilesional cortical areas.
3. Attempted motor execution: In real-time, the patient tries to replicate these movements while receiving **positive visual feedback**. It reduces the feeling of failure, restores coherence between intention and perception and induces **high cortical activation** that favors neuroplasticity.

Action Observation
Observing movements without physical execution activates the cortical areas called upon during movement execution.

Motor imagery with visual support
Imagining the execution of a movement, with the visual support offered by IVS, reinforces cortical activity and simplifies the task of imagination.

Movement Execution
Performing movements, or trying to perform movements with IVS enables a very broad activation of the sensori-motor connectome.

Positive visual feedback
Reducing the feeling of failure encourages learning, participation and brain plasticity.

Factors enhancing cortical activation

Future perspectives

IVS is emerging as a key rehabilitation device for targeted sensorimotor network activation.

Can early IVS-supported cortical activity testing predict the **recovery trajectory of acute post-stroke patients**? This active research topic is currently discussed with clinicians and researchers.

Cognitive and motivational aspects

Cognitive and motivational dimensions are key factors in movement production, (motor) learning processes, and effective rehabilitation interventions. By combining immersive visual stimuli with tailored rehabilitation protocols, IVS provides a complementary approach to conventional therapies.
This section explores relevant aspects of these themes that focus on involved neuropsychological mechanisms and observed clinical benefits.

Contributions of the IVS technology

1. Cognitive engagement

IVS mobilizes several essential cognitive processes:

- Attention: Immersive IVS environments **enhance patient's focus**, by adjusting the complexity of movements and relevant/distractive information.
- Planning: Patients progressively anticipate and prepare their movements based on the presented visual models, stimulating their ability to organize their motor tasks. The use of objects further supports **motor intention** through an imitation-based execution.
- Working memory: Repetition of motor sequences reinforced by visual stimuli enhance recall and consolidate movement production steps. It also allows **complex movement sequencing**.

2. Motivation and adherence

The immersive and engaging nature of IVS improves patient participation:

- Motor impulse and kinesthetic illusion: The perception of the body in motion induces a kinesthetic illusion that increases motivation to move.
- Feedforward & Feedback mechanisms: Visual representation of movements on screen support two main control mechanisms:
  - ***Feedforward:*** A passive observation that enhances movement preparation.
  - ***Feedback:*** An active session where patient performs a movement and sees the results of movement attempts on the screen. This **modified feedback** supports **motor learning and engagement**.
  - Gamification: The interactive nature of IVS transforms repetitive exercises into **engaging and meaningful activities**, often involving objects relevant for **activities of daily life (ADLs)**.

Cognitive engagement

Attention

Planning

Working memory

Motivation & adherence

Motor impulse

Feedforward & feedback

Playful experience

Improvements achieved with IVS during rehabilitation

Future perspectives

Ongoing research explores the **relevance of cognitive and motivational processes** in post-stroke recovery. The goal is to integrate a **holistic patient-centered approach** into clinical rehabilitation programs and research projects.

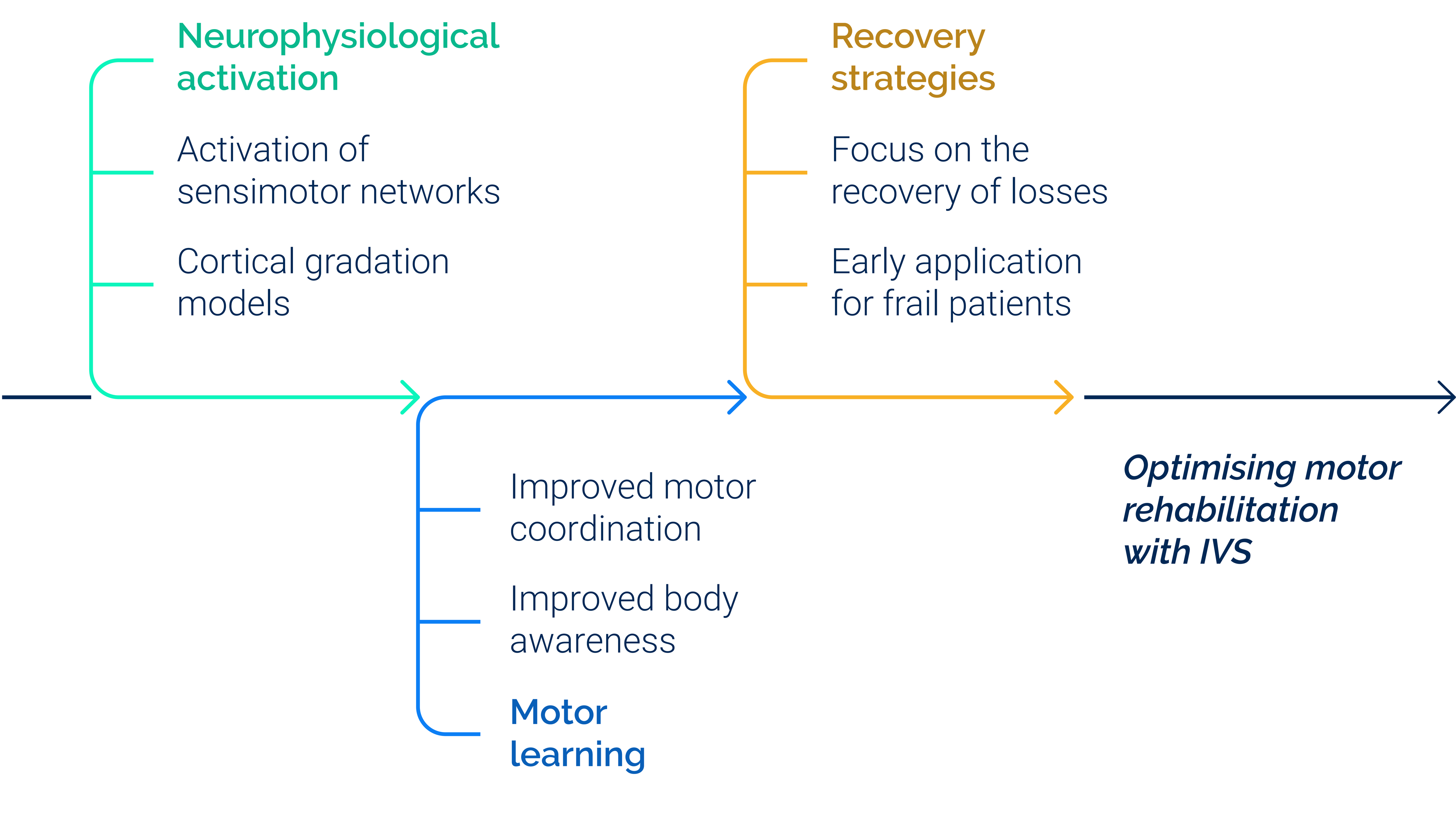
Clinical implications

The IVS helps to prevent the **learned non-use and motor exclusion**, originally described by **Taub et al.**[6], in both behavioral and cortical aspects. Additionally, IVS is used for **fine motor rehabilitation, tonus reduction, and chronic pain management**.

Although **upper limb (UL) and lower limb (LL) rehabilitation** differ in specific methodologies, they share **common learning principles, cortical stimulation strategies, and compensation-prevention mechanisms**. IVS is proven effective for both UL and LL rehabilitation. This section proposes to discuss these similarities and differences, and to highlight the contribution of IVS in each context.

Similarities between UL and LL rehabilitation

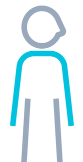
- Neurophysiological activation
  Studies (e.g., **Adham et al.**[5]**, 2024**) show that IVS significantly activates sensorimotor networks for both UL and LL. The same cortical gradation pattern was observed during different situations: Observation, Imagination, Motor execution. The use of visual feedback does not seem to be differentiated between UL and LL.
- Motor learning support
  Whether grasping an object or taking a step, IVS improves **body awareness, motor representation and coordination**.
- Recovery vs. Compensation
  Rehabilitation should prioritize **functional recovery overcompensation** whenever possible. IVS is beneficial for **severely affected patients** and can be introduced in an **early acute rehabilitation phase** to enhance body awareness, movement intention, and reduce **spatial neglect**.



Improved motor rehabilitation with IVS UL and LL

5: Adham, A., Le, B. T., Bonnal, J., Bessaguet, H., Ojardias, E., Giraux, P., & Auzou, P. (2024). Neural basis of lower-limb visual feedback therapy: An EEG study in healthy subjects. Journal of NeuroEngineering and Rehabilitation, 21(1), 114. https://doi.org/10.1186/s12984-024-01408-8 | 6: Taub E, Uswatte G, Mark VW, Morris DM. The learned nonuse phenomenon: implications for rehabilitation. Eura Medicophys. 2006 Sep; 42(3):241-56. PMID: 17039223.

Differences between UL and LL rehabilitation



Upper Limb (UL)

- Fine motor skills: UL rehabilitation primarily focuses on analytic and simple movements and then on functional movements like grasping. IVS is efficient for motor planification and for correcting praxis abnormalities by using immersive visualization of the movements.
- Interaction with objects: UL are often involved in complex functional tasks that require direct interaction with the environment.
- Unilateral attentional focus: IVS for UL allows that observation and motor execution are isolated to the affected limb only. This reduces the attentional and cognitive costs for the patient compared to bimanual mirror therapy. In this context, motor functions and the activation of injured limb should be strengthened before moving on to bimanual functional activities (also possible with IVS).
- The first-person visual perspective in IVS strengthens the **eye-hand connection**, thereby improving body awareness and coordination.

Lower Limb (LL)

LL rehabilitation is conducted either in a **seated or a standing position**, depending on the patient's profile, the recovery stage and the rehabilitation goals, i.e. it enables the therapist to adapt to the current status of the patient and progress accordingly.

Seated position

- Analytic movements: A seated training mainly focuses on **body awareness and movement intention to prepare for standing phase**. Focus on the control over lower limb segments, with specific exercises like dorsiflexion.
- Unilateral engagement: IVS is **primarily unilateral**, targeting the affected limb to stimulate active motor participation in anticipation of weight-bearing activities.
- First and third-person perspectives: IVS provides **multiple viewpoints**, offering patients **enhanced visualization of ankle and foot movements. Change of perspective will help** to reinforce motor representation and control.

Standing position

- Rhythmic movements and postural stability: In standing positions, the focus shifts towards functional motor schemes, **like walking, weight transfers, and postural stability**.
- Uni- or bilateral engagement: LL rehabilitation requires the **synchronization of both limbs**. Functional gait or walking training involves **alternating stability and propulsion phases** to achieve efficient ambulation.
- Global coordination: Balance and gait training must include the lower limbs and the trunk that represents the center of mass. The two lower limb segments must work synergistically, with good **inter-segmental coordination** and a precise **trunk control**. IVS will help to support the overall participation of the LLs and to gradually include a dynamic balance and trunk control. This complex coordination must often be **supported and gradually relearned by patients** before they are able to regain movement automation and prevent the development of deleterious compensations.

	Upper limbs	Lower limbs
Motor control	*Rythmic movements*	*Fine coordination*
Interaction with environment	*Complex functional tasks*	*Stabilisation & coordination*
Unilateral Vs bilateral commitment	*Bilateral coordination*	*Unilateral focus*
Rehabilitation perspectives	*First-person perspective*	*Various perspectives*

Improved motor rehabilitation with IVS UL and LL

Bridging science and practice: evidence-based integration of new technologies into clinical practice

Efficacy of neurorehabilitation programs often hinges on strategic integration of **scientifically validated, user-friendly technologies** that collectively address the multidimensional nature of movement and motor control.

Evidence based devices like IVS enhance cognitive engagement and cortical activation through mental imagery by reducing cognitive demand and promoting lateralized brain activity (see above).

However, it's relevant to note that only the construction and implementation of a holistic framework which combines validated devices and approaches - will address the multifaceted components of motor control:

- Robot-Assisted Therapy (RAT) enables high-dose, precise movement repetitions that are critical for neuroplasticity and minimize the therapist strain through adjustable, programmable exoskeletons (e.g. the ArmeoSpring, Hocoma, Switzerland).
- Functional Electrical Stimulation (FES) bridges intention and actions by detecting motor intent (via EMG or movement patterns) to trigger muscle activation and enable functional task executions (e.g. grasping, gait and balance).
- Neuromodulation (e.g., transcranial direct current stimulation, tDCS, transcranial magnetic stimulation TMS) modulates cortical excitability, confirming its adjuvant role in improving motor recovery when paired as add-on to other conventional therapies.

These devices are not exclusive. A smart combination of various stimulations to reach a pre-defined goal may amplify the therapeutic impact and support recovery in patients:

- IVS + FES: Stroke patients use IVS to train specific muscle activations and restart specific walking patterns, then FES supports muscular activation of the dorsiflexors to improve gait.
- IVS + RAT: IVS primes motor planning and body awareness, while the robotic device (RAT) supports motor impulses into physical practice. Working on IVS before RAT will favor the patient's participation and bridge the gap between motor attempts and actual movement execution.
- Neuromodulation: Neuromodulation will support the interhemispheric balance and/or modulate cortical activation to improve efficacy of the stimuli.

Improved motor rehabilitation with IVS UL and LL

The presented modalities must be considered as stand-alone therapeutic devices (approaches) that serve as a complementary therapeutic toolkit to facilitate an efficient integration into the patient-centered rehabilitation process.
Modality selection and combination strongly depend on the patient's impairments along with his/her goals that allow an individual integration of the selected modalities with the traditional therapies. The clinician tailors interventions to maximize the individual outcomes.

The presented devices are prioritized not only for their **efficacy** but also for their **clinical ease for implementation**. Clinicians determine and tailor the program to fit their patients' needs: they control their progression to individually adapt the selected exercises intensity into the program. This will allow to embed all functional gains into meaningful daily activities.

The combination of perceptual-cognitive-action (IVS), mechanical assistance (RAT), neuromuscular facilitation (FES), and cortical modulation allow the rehabilitation programs to achieve **synergistic and cumulative effects** that will accelerate functional recovery, optimize dose-intensity, and improve patients' autonomy and quality of life.

> Patients, with their impairments, their disabilities, their projects and their goals as well as their hopes must always stay at the core of our model.

Directly translating motor control theory into practice, this kind of integration closes the science-to-clinic gap, ensuring patients benefit from innovations while maintaining the **human-centric core of rehabilitation**.

Conclusion

The IVS technology is an essential and unique tool for functional rehabilitation. Its impact extends far beyond a purely mechanical approach to movement, offering a more holistic perspective.

It is difficult to dissociate perceptual, cognitive, attentional, and motor components from one another. Several researchers have worked on integrated models of **perception, cognition, and action**, yet these models are not always well incorporated into rehabilitation programs or proposed in a comprehensive, non-fragmented manner.

As we look to the future of rehabilitation, it is evident that innovative and integrative approaches such as IVS represent a significant step toward more complete and effective patient care. However, many areas remain to be explored to refine its use and maximize its clinical benefits.

Perception
The initial process of receiving and interpreting sensory stimuli

Cognitive processing
Analysing and interpreting perceived information to make decisions

Motor intention
Formulating a plan or intention for a movement

Motor execution
Physical execution of the planned movement

Analysis of the result
Evaluating the success and the effectiveness of the movement

Learning and automation
Integration of this motor component into the motor repertoire

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