IMMERSIVE
NEUROLOGIC
REHABILITATION

Summary

1. Introduction

a. Why the INR Method (Immersive Neurologic Rehabilitation)

Traditional rehabilitation methods rely on the technique and the relationship between the therapist and the patient (6). The repetition of sessions leads to fatigue, resulting in a decrease in effectiveness.
The INR method is based on specific exercises and on motivational encouragement as well as the enjoyment of the game felt by the patient (5). It is a comprehensive method made available to the therapist that groups exercises by pathology, allowing for the specific management of patients.

b. To which types of patients the INR method is addressed

Our software can treat a wide range of neurological conditions: strokes, degenerative diseases such as Parkinson's disease and Alzheimer's disease, headaches, neuropathies, multiple sclerosis, movement disorders, sleep disorders, and neuromuscular disorders.

2. What is the INR Method?

a. Recap of the Central Neurological System's Functioning

Our brain is built on the communication between neurons belonging to 4 major neurological systems:

- *The frontal cortex*: the site for muscle coordination, head movements, memory centers, decision-making, and reasoning by analogy. It is connected with the basal ganglia.
- *The motor nervous system*: it enables the execution of movements by the locomotor system.
- *The sensory nervous system*: it sends to the central cortex all the information concerning the surrounding environment, peripheral sensitivity, and the analysis of movement.

- *The sympathetic nervous system*: it automatically regulates vital functions, including cardiac, digestive, and respiratory functions.

Neurosciences have shown the presence of areas that activate during pleasure, which are intersections between the different neurological systems constituting the brain. There are 2 loops allowing neurons to communicate through these intersections. When stimulated, the first loop leads to satisfaction, while the second loop decreases this sensation. The use of augmented reality allows the brain to integrate a safety dimension into the execution of the exercise. By invoking memory, integrating the instructions proposed by the therapist, and using augmented reality, the INR method enables an action that engages the satisfaction loop. The INR method is based on the positive reinforcement obtained from the successful completion of exercises (1)(2). The objectives are clear because they are determined by the ILR system and commented on by the therapist. Trust in the therapist is essential to gain the patient's adherence, obedience, and thus achieve the desired result. The playful aspect helps to reduce the tedious, repetitive nature of the sessions, making them a moment of enjoyment. (4)(5)
Through this method, therapists can increase the motivation and commitment of the patient towards healing, with the diversity of exercises increasing their chances of success.

b. Content

The INR method allows the therapist to identify the most useful exercises based on the pathology and the general condition of the patient. We have distinguished the following types of exercises:

- **Fine motor skills exercises:** To improve coordination and dexterity of hands and fingers.
- **Physiotherapy:** To strengthen muscles, improve balance and walking.
- **Cognitive exercises:** To enhance memory, attention, problem-solving, and other cognitive functions that may be affected.
- **Art Therapy:** These therapies help to improve mood, reduce anxiety, and also stimulate cognitive and motor functions.
- **Relaxation and stress management exercises**
- **Exercises to improve gross motor skills**

3. Fine Motor Skills Exercises

In the treatment of patients with neurological disorders in the hospital, fine motor skills exercises are crucial for improving dexterity, coordination, and the function of the hands and fingers. These exercises are often supervised by occupational therapists, physiotherapists, or other rehabilitation professionals. We have thus adapted the classic exercises into a virtual reality environment:

a. Object Manipulation

The object manipulation exercises are as follows:

- **Cube Tower**, in C2Physio, the goal is to stack cubes that are picked up from a plan on the left and placed on a plan on the right. The parameters are the number of cubes to stack (from 1 to 4) and their size (from 7cm to 1cm).
- **Shelving**, in C2Physio, the goal is to shelf a set of items in a supermarket shelf.
- **Item Grabbing**, in C2Physio, the goal is to take all the items from a supermarket shelf and place them in a shopping cart.
- **Basketball**, in C2Physio, the goal is to grab a ball from the side and throw it into a basket.

b. Drawing Exercises

All the drawing exercises are performed using **3D Drawing** in C2Physio. We advise performing the following exercises:

- **Draw basic shapes**, circles, squares, triangles, and rectangles. Then progress to more complex shapes such as stars, hearts, moons, suns, leaves, flowers, butterflies, clouds.
- **Trace lines**, trace lines in different directions vertical, horizontal, diagonal but also progress by integrating the depth dimension. Possibility also of transforming the line into a zig-zag to improve movement control.
- **Draw patterns**, by reproducing simple patterns like fish scales. This encourages repetition and consistency of gesture while improving concentration.

- **Draw everyday objects**, draw everyday objects such as a cup, a book, a chair, focusing on proportions and perspectives. This stimulates visual perception and spatial representation capacity.
- **Coloring**, go back to the first exercise on drawing basic shapes and ask the patient to color the center, focusing on staying within the lines. Coloring is both relaxing and helps to improve the precision of the gesture.
- **Use both hands**, repeat the first exercise using the non-dominant hand. This helps to stimulate the areas of the brain involved in motor skills and coordination.

c. Game

We will use the game "Attracted!" which requires concentration and fine motor skills to move the game characters. Indeed, it is necessary to maintain a position using a laser pointer and slowly move this pointer.
Depending on the patient's abilities, the movement of the pointer can be done by rotating the shoulder, elbow, or wrist. The movement can be performed with the arm in the air or resting on a table, for example.
The notion of the game will make the exercise stimulating despite the possible difficulties the patient may encounter.

4. Physiotherapy

In a neurological context, we recommend applying the following exercises:

a. Balance and Walking Exercises

For balance exercises, we recommend using vestibular exercises contained in the C2Physio app. We advise you to consult the C2Care Physio Method document for more information on this topic.
Regarding walking exercises, we recommend two exercises from the C2Physio app: Dance and Foot - Feet. These two exercises will help stimulate the lower limb of the patient.

b. Muscle Strengthening Exercises

We recommend using the C2Physio app with Squats exercises for the lower limbs as well as the Fencing exercise.
Both exercises can be used with a type of elastic constraint to increase resistance.

In general, we invite you to refer to the C2Care Physio Method for a detailed description of the Physiotherapy part offered with C2Care applications.

5. Cognitive Exercises

Cognitive exercises are essential in managing neurological problems because they help maintain or improve brain functions, memory, attention, problem-solving abilities, and other aspects of cognition. Here are examples of cognitive exercises specifically adapted for the rehabilitation of patients with neurological disorders.

a. Memory Games

Memory games are extremely useful in the context of neurological disorders because they directly target and stimulate essential cognitive functions. By regularly practicing these games, patients can work on their ability to remember short-term information, which is often one of the first capabilities affected by these disorders. Over time, this stimulation can also help strengthen long-term memory through repetition and sustained cognitive engagement.

These activities encourage brain plasticity, the process by which the brain adapts and reorganizes in response to new information and experiences. This is particularly valuable for individuals suffering from neurological disorders, as it can help compensate for damaged or lost brain functions.

Success in these games also improves patients' self-confidence and self-esteem. They can be adapted to different levels of difficulty to meet the specific needs of each patient, allowing for a personalized treatment approach essential for the effectiveness of neurological rehabilitation.

We will use the Memory game from the C2Brain app. It contains 5 levels of difficulty, allowing adaptation according to the patient.

b. Executive Function Exercises

Executive function exercises are crucial for individuals with neurological disorders because they target key skills such as planning, decision-making, and problem-solving. By strengthening these functions, patients can better manage daily activities and improve their independence. Executive function training stimulates brain plasticity, promoting rehabilitation and the improvement of cognitive abilities, crucial for recovery and independence.

Furthermore, these exercises also help regulate emotions and improve social interactions by developing the ability to control impulses and consider the consequences of actions. This improvement in emotional regulation and social behavior is beneficial for patients' quality of life.

Finally, the variety and adaptability of these exercises allow for treatment personalization, ensuring that interventions are appropriate and engaging for each patient. This makes the rehabilitation process more effective and motivating, significantly contributing to the management of neurological disorders.

For planning, we will use the Gold Seeker game from the C2Brain app. It allows planning a series of actions to complete a level. The game contains 50 levels to ensure that any type of patient does not face failure.
The Save Me game will focus more on puzzles and logical brain teasers. Similar to the previous game, it contains 50 levels.

c. Visuo-Spatial Training

Visuo-spatial training plays a crucial role in the rehabilitation of patients with neurological disorders, focusing on improving spatial perception, hand-eye coordination, and the ability to navigate space. These skills are fundamental for performing daily tasks such as reading, writing, driving, and moving independently. By stimulating and strengthening visuo-spatial functions, patients can better

understand and interact with their environment, which is essential for their autonomy and quality of life.

The flexibility of these exercises allows customization based on the needs and abilities of each patient, making the training both accessible and challenging. This personalization ensures that patients remain engaged and motivated throughout their rehabilitation journey, maximizing the chances of success in managing their neurological disorders.

We will use the Supermarket exercise from the C2Physio app, an ecological exercise in which you have to buy a list of items in a supermarket. The exercise combines both a visuo-spatial exercise and a memory exercise.

6. Art Therapy

Art therapy, through activities such as drawing and sculpting, offers significant benefits for the brain and neurological function, especially for individuals suffering from neurological disorders. Here is a description of the neurological contribution of these artistic practices:

a. Drawing

Drawing activates several brain regions involved in motor skills, visual perception, and planning. This activity stimulates hand-eye coordination and motor precision, essential for daily tasks. Neurologically, drawing can promote neuroplasticity, the process by which the brain adapts and forms new connections in response to learning and experience. By focusing on visual creation, patients may also see improvements in attention and concentration areas, thereby reducing symptoms of anxiety and depression by providing a means for emotional expression and distraction from negative thoughts.
Through the 3D Drawing module, virtual reality offers a new and stimulating drawing experience for the patient.

b. Sculpture

Sculpture engages the brain in a unique way by combining visuo-spatial perception and movement, which can enhance the ability to interpret spatial

stimuli and manipulate objects in a three-dimensional space. This activity solicits and strengthens neural circuits associated with fine motor skills and spatial planning.
Implementing sculpture in practice is challenging, mainly due to the manipulation of materials. Virtual reality here unleashes its full potential by allowing sculpture with a sense of depth and the practical and quick setup.

7. Relaxation and Stress Management Exercises

Relaxation and stress management exercises play a crucial role in the management of neurological disorders, contributing to reducing symptoms and improving the quality of life for patients. These techniques help to decrease bodily tension, calm the mind, and enhance mood, which is particularly beneficial for individuals suffering from neurological conditions, often accompanied by increased stress and anxiety. Here are the exercises to perform:

a. Breathing Techniques

Deep Breathing: Encourage patients to focus on their breathing, inhaling deeply through the nose, holding their breath briefly, and then exhaling slowly through the mouth. This helps to calm the nervous system. This technique is explained through the Breathing Aid option in C2Relax environments. This option allows configuring the inhalation/exhalation time and provides a visual cue for the patient to synchronize their breathing with it.

b. Meditation and Mindfulness

Guided sessions that help focus the mind on the present moment, reducing intrusive thoughts and stress. With the C2Hypno application and in the environment of their choice, the patient will be guided through different hypnosis scripts, either of the mindfulness type or on more specific themes, such as chronic pain, stress management, or self-confidence.

c. Biofeedback

Use devices that measure physiological functions to teach patients how to voluntarily control these responses, thus reducing stress and anxiety. The device can be directly connected to our interface, and the patient can visualize their heart rate directly in the virtual reality headset.

When these techniques are regularly integrated into care for neurological disorders, they can help patients better manage symptoms of stress and anxiety, thereby improving their ability to cope with their condition. It is important that these exercises are tailored to the patient's abilities and needs, and that they are practiced under the guidance of a qualified health professional to ensure their effectiveness and safety.

8. Clinical Cases

a. George: 67 years old, obese, suffered a stroke

- **Pre-therapeutic Evaluation**

George, 67, is obese with a BMI of 32 and recently suffered a stroke, leading to right-sided hemiplegia and moderate cognitive difficulties, including memory and concentration issues. The initial assessment also reveals signs of depression and anxiety. George struggles with daily tasks and expresses a desire to regain some independence.Evaluation Pré thérapeutique.

- **Strategy Determination**

George's rehabilitation strategy focuses on four main areas: mobility, cognitive functions, stress and anxiety management, and weight reduction to improve his overall health and prevent further complications.

- **Implementation**

George follows a structured program, starting with physiotherapy sessions three times a week, occupational therapy sessions for cognitive functions, and weekly

art therapy and meditation sessions. Dietary adjustments are recommended, with follow-up by a nutritionist.

- **Evaluations and Adaptations**

George's progress is evaluated every two weeks. Adjustments are made based on his evolution, with a gradual increase in the intensity of physical exercises and the introduction of new cognitive activities to maintain the challenge. George's response to stress management techniques is monitored, with adaptations based on his preferences and comfort level.

- **Outcome**

After six months, George shows significant improvements in his ability to walk with assistance, an increase in muscle strength in the affected limbs, and better coordination. Cognitively, he reports improvements in memory and concentration. George has also managed to lose 5% of his initial weight, contributing to his overall well-being. He reports a notable reduction in his anxiety and depression, attributing much of this improvement to relaxation and art therapy sessions. George continues to work on his rehabilitation goals with the care team, motivated by the progress made.

b. Hélène: 59 years old, physically fit, diagnosed with Parkinson's

- **Pre-therapeutic Evaluation**

Hélène, 59, is diagnosed with Parkinson's disease. Despite being physically fit, she begins to experience resting tremors, muscle stiffness, and difficulties with fine movements. She also notices a slight decline in her concentration ability. Helen, active and independent, wishes to maintain her activity level and slow the progression of her symptoms.

- **Strategy Determination**

Helen's rehabilitation strategy focuses on maintaining her mobility, managing specific symptoms of Parkinson's, improving cognitive function, and emotional support.

Mobility and Motor Control: Integration of physical exercises targeting flexibility, balance, and strength, with an emphasis on tai chi and dance, known for their benefits in Parkinson's patients.
Cognitive Functions: Use of cognitive exercises to stimulate attention, working memory, and executive functions, incorporating problem-solving activities and strategy games.
Management of Tremors and Rigidity: Application of specific relaxation and stretching techniques to reduce muscle rigidity and control tremors.
Emotional Support: Implementation of art therapy sessions and support groups to help Helen express her emotions and manage the psychological aspects of Parkinson's disease.

- **Implementation**

Hélène attends physiotherapy sessions twice a week. She also participates in weekly cognitive workshops and attends art therapy and support group sessions once a week.

- **Evaluations and Adaptations**

Hélène's progress is evaluated monthly. Adjustments to her program are made based on her responses to exercises and therapies. The intensity and variety of physical activities are gradually increased to match her improvements and motivation. Cognitive and emotional strategies are regularly reassessed to ensure they meet her evolving needs.

- **Outcome**

After three months, Helen shows a noticeable improvement in mobility and a reduction in stiffness and tremors. She reports feeling more alert and able to concentrate on complex tasks more easily. Helen finds great comfort and a means of expression in art therapy and feels significant support from the support groups. Encouraged by her progress, she remains committed to her rehabilitation program, confident in her ability to manage the symptoms of her disease and maintain a high quality of life.

c. Suzie: 47 years old, physically fit, diagnosed with Alzheimer's

- **Pre-therapeutic Evaluation**

Suzie, 47, is in good physical shape but has recently been diagnosed with early-onset Alzheimer's disease. Initial symptoms include short-term memory loss, difficulties planning or organizing tasks, and slight disorientation in unfamiliar places. Despite these challenges, Suzie is determined to stay active and maintain her independence as long as possible.

- **Strategy Determination**

For Suzie, an integrated plan aimed at supporting her cognition, physical fitness, and emotional well-being is developed, focusing on:

Cognitive Strengthening: Incorporation of memory exercises, such as card games, puzzles, and mobile apps designed to train memory and attention. The use of journals or electronic planners to assist in the management of daily tasks.
Physical Exercises: A regular exercise program including running, cycling, and swimming to promote cardiovascular health and potentially slow the disease's progression. Introduction to yoga and Pilates to improve flexibility, balance, and concentration.
Art Therapy and Music Therapy: Weekly art therapy sessions to encourage emotional expression and music therapy to stimulate memory and mood through music.
Social Activities: Participation in support groups and community activities to maintain social skills and combat isolation.

- **Implementation**

Suzie engages in a daily physical exercise program suited to her fitness level, participates in art therapy and music therapy sessions twice a week, and uses cognitive tools and apps for memory enhancement every day. She also incorporates regular social gatherings into her schedule.

- **Evaluations and Adaptations**

Suzie's progress is evaluated every two months to adjust activities to her evolving needs and responses to interventions. The intensity levels of physical exercises are

adapted based on her endurance and motivation. Cognitive activities are updated to offer ongoing challenge, and art therapy and music therapy options are reviewed to match her changing interests.

- **Outcome**

After six months, Suzie shows a notable stabilization in her cognitive functions and reports an improvement in her emotional well-being. She finds great comfort and engagement in art therapy and music therapy sessions and particularly appreciates the social support she receives through support groups. Although Alzheimer's disease is progressive, Suzie's proactive approach to managing her health and well-being allows her to maintain a high quality of life and remain as independent as possible.

d. Jason: 26 years old, in excellent physical condition, suffering from post-concussion syndrome

- **Pre-therapeutic Evaluation**

ason, a 26-year-old man in excellent physical condition who regularly engages in high-level sports, recently suffered a concussion during a sports competition and now exhibits persistent symptoms such as headaches, concentration difficulties, increased sensitivity to light and noise, and mild emotional instability, characteristic of post-concussion syndrome.

- **Strategy Determination**

Jason's rehabilitation plan focuses on managing post-concussive symptoms, cognitive and physical recovery, and preventing recurrences.
Symptom Management: Relaxation and stress management techniques, such as deep breathing and meditation, to help control headaches and emotional instability.

Cognitive Rehabilitation: Initially light cognitive exercises, such as memory games and concentration tasks, gradually increasing in difficulty to stimulate cognitive recovery without overloading the brain.

Graduated Physical Activity: Gradual resumption of physical activity, starting with light exercises like walking or yoga, with careful monitoring of symptoms. Gradual increase in intensity based on Jason's tolerance.

- **Implementation**

Jason starts with daily stress management sessions and cognitive rehabilitation sessions three times a week. He gradually resumes physical activity with light walking sessions, progressively increasing intensity under medical supervision. Regular consultations are scheduled for education on symptom management and prevention.

- **Evaluations and Adaptations**

Jason's symptoms are evaluated weekly to adjust the rehabilitation program accordingly. Cognitive and physical exercises are modified based on his progress and response to treatment. Stress management techniques are adapted to maximize their effectiveness.

- **Outcome**

After three months, Jason reports a significant decrease in his headaches and an improvement in his concentration. He has resumed most of his physical activities at a less intense level while remaining vigilant for signs of overexertion. Jason has also developed effective strategies for managing his stress and emotions. Although recovery from post-concussion syndrome can vary among individuals, the multidisciplinary and adaptive approach has allowed Jason to make significant progress toward recovery while taking preventive measures against future concussions.

9. Conclusion

The INR method combines specific pathologies and general state alterations with augmented reality and virtual reality care. It is a comprehensive method made available to the therapist as a tool to complement their own practice. To our knowledge, this method is pioneering.

As technology evolves rapidly, it directly influences practice. C2Care closely follows technological developments and will do everything in its power to integrate them

and make them available through software updates. C2Care thus invites you to collaborate in this improvement by collecting your opinions and proposals, and to advance research.

"There is no need to hope in order to undertake, nor to succeed in order to persevere" - William I of Orange Nassau

10. Bibliography

1. Gelineau et al. (2021) on patient engagement and motivation via video games in a therapeutic context.

2. Rose et al. (2010) Training in virtual environments: Transfer to real world tasks and equivalence to real task training

3. Maureen et al. (2005) Virtual Environments for Motor Rehabilitation

4. Kato (2010) on the use of mainstream video games in the health field, particularly for children with cancer.

5. Gillet & Jung (2019) on the use of video games as a means of symbolization and subjectivation within therapeutic groups.

6. Leroux (2009) and Duris (2022) on the creation of the therapeutic alliance between patient and therapist via video games.