Beyond the Lesion: How Neurobypass 1.0 Transforms Post-Stroke Rehabilitation for Motor Recovery

Isabella Camily Nato Rosa[1]*, Raphael Akira Siqueira Ishibashi[1], Atala Portella[1], Daniel Gomes Almeida Filho[1]
[1]SENAI CIMATEC University; Salvador, Bahia, Brazil

Stroke is one of the leading causes of death and functional disability in Brazil, significantly impacting survivors' quality of life. The Neurobypass 1.0 project proposes an innovative approach to post-stroke motor rehabilitation through a neuro-controlled hand and wrist orthosis. Developed by SENAI CIMATEC in partnership with CEPRED, the device uses brain-computer interface (BCI), virtual reality (VR), and additive manufacturing (3D printing) to promote engagement, customization, and neuroplasticity stimulation. A systematic review identified evidence for the efficacy of BCI and AR orthoses in enhancing function and motivation in patients with hemiparesis. A randomized clinical trial protocol was designed to assess motor, emotional, and motivational outcomes of the intervention. Expected results include functional hand recovery, reduced depressive symptoms, and greater independence. The initiative highlights Brazil's potential as a reference in accessible assistive technologies.
Keywords: Stroke. Rehabilitation. Brain-Computer Interface. Virtual Reality Therapy.

Stroke, as defined by the World Health Organization (WHO), is a severe condition caused by the interruption of cerebral blood flow, which can lead to irreversible damage or death [1,2].

In Brazil, it is the leading cause of death among individuals over 50 and of early retirement, with around 200,000 hospitalizations by the Sistema Único de Saúde (SUS)in 2008 and 99,010 deaths in 2020 [3,4]. Motor sequelae, such as upper limb weakness, affect basic daily activities (eating, hygiene, dressing) and more complex occupational tasks [5].

The Neurobypass 1.0 project, developed by the SENAI CIMATEC Assistive Technologies Competence Center in partnership with the Center for the Prevention and Rehabilitation of Disabilities (CEPRED), proposes an innovative solution for post-stroke rehabilitation. The project involves a neuro-controlled hand and wrist orthosis utilizing a brain-computer interface (BCI) with electroencephalography (EEG) to capture neural signals and control the device through a mechatronic system that simulates tendon movements.Integration with augmented reality (AR) shows potential for increasing patient engagement and stimulating neuroplasticity [6,7]. Additive manufacturing (3D printing) enables customization of the device to the anatomical features of each user, improving efficacy and comfort [8]. The goal is to stimulate neuroplasticity through a technologically advanced, personalized therapeutic approach [9].

A multidisciplinary team conducts the project to ensure the development of an ergonomic and practical device that can maintain user motivation throughout the rehabilitation process.Thus, Neurobypass 1.0 not only advances motor rehabilitation but also strengthens Brazil's standing in assistive technology innovation, promoting access to cutting-edge devices and enhancing independence and quality of life for post-stroke patients.

The primary objective of developing a neuro-controlled hand exoskeleton is to facilitate motor function rehabilitation in stroke survivors. With a personalized approach tailored to each individual's needs, the device aims to restore hand function by stimulating the brain's neuroplasticity through interfaces that enable control of the device via brain activity.

Received on 17 March 2025; revised 20 May 2025.
Address for correspondence: Isabella Camily Nato Rosa. Av. Orlando Gomes, 1845, Piatã, Salvador, Bahia, Brazil. Zipcode: 41650-010. E-mail: isabella.nato@fbter.org.br.
Original extended abstract presented at SAPACT 2025.

J Bioeng. Tech. Health 2025;8(3):253-255

Materials and Methods

The project's first phase involved a systematic literature review across various databases, including PubMed, Scopus, Web of Science, Cochrane Library, and PEDro, using descriptors such as "Stroke rehabilitation," "Orthotic devices," "Brain-Computer Interface," and "Virtual Reality therapy." Clinical trials evaluating BCI orthoses, with or without VR, for the rehabilitation of post-stroke hemiparetic patients were selected for this review. Following the review, a comprehensive informational report was produced, covering neuroanatomy, stroke pathophysiology, post-stroke rehabilitation, the effectiveness of orthoses, and the role of BCI in neuromotor recovery. Based on the results of this review, the multidisciplinary team developed a clinical trial protocol with strict inclusion criteria (muscle strength ≥3, absence of severe cognitive deficits). Assessments will be conducted over 12 weeks using functional (dynamometer, Ashworth Scale, Barthel Index, Fugl-Meyer) and psychological (Beck Depression Inventory, Perceived Self-Efficacy Scale) tests. The assessments will follow CNS Resolution 466/12, with assessments conducted by a multidisciplinary team.

Results and Discussion

The literature review identified thirty-one studies with BCI-based orthoses and six with VR.VR has demonstrated high potential for increasing engagement, motivation, and therapeutic adherence by transforming repetitive exercises into interactive and stimulating experiences. Studies have shown that orthoses with brain-computer interfaces (BCIs) and virtual reality (VR) have a positive impact on

post-stroke rehabilitation. VR, by making exercises more interactive and immersive, increases user motivation and engagement—essential factors for better functional outcomes.

Based on these findings, a protocol was developed for a randomized, double-blind, case-control clinical trial using the Neurobypass 1.0 neuro-controlled orthosis. Assessments will be conducted at baseline and after 4, 8, and 12 weeks, including physical exams, functional assessments (grip dynamometer, Ashworth Scale, Barthel Index, Fugl-Meyer Scale), and psychological/motivational evaluations (interviews, psychological tests, cognitive and quality-of-life instruments).

The systematic review also underscored the importance of patient motivation, which directly influences therapeutic results, with motivated individuals tending to achieve greater gains [10].

Post-stroke patients frequently face emotional challenges such as depression, anxiety, and post-traumatic stress, with up to 30% developing significant depression [11]. Self-Determination Theory emphasizes that motivation during the subacute stroke phase is influenced by extrinsic factors, such as positive feedback, which can potentially evolve into intrinsic motivation through the satisfaction of basic psychological needs [12].

It was concluded that validated instruments, such as the Beck Depression Inventory (BDI-II) and the Perceived Self-Efficacy Scale, are essential for assessing emotional state and inferring motivation, especially given the lack of specific tools in Brazil.These instruments evaluate depressive symptoms and hopelessness, which directly impact motivation and engagement in rehabilitation, contributing to more effective, personalized therapeutic strategies.

Thus, combining advanced technologies like BCI and VR with robust psychological and functional assessments offers a promising path for post-stroke rehabilitation, aligning with the clinical and emotional needs of users.

Conclusion

Neurobypass 1.0 represents progress in post-stroke rehabilitation by combining brain-computer interface (BCI), additive manufacturing (3D printing), and virtual reality (VR) to develop an ergonomic, personalized neuro-controlled hand exoskeleton. The device aims to improve motor function, stimulate neuroplasticity, and enhance therapeutic engagement, thereby aiding in the resumption of daily activities and promoting functional independence. Beyond motor benefits, the project aims to achieve scientific validation through clinical trials, thereby contributing to a deeper understanding of neuroplasticity.

In addition, Neurobypass 1.0 relies on a multidisciplinary team to adopt a biopsychosocial approach. This means the project considers not only the physical aspects of the patient, but also the psychological and social factors. The team assesses how the use of new technologies in rehabilitation impacts the user's experience and motivation, which, in turn, can directly influence the results obtained at the end of the treatment.

Neurobypass 1.0 also has the potential to position Brazil at the forefront of assistive technologies, with possible implementation in the public healthcare system (SUS), democratizing access to innovative rehabilitation and improving patient quality of life.

References

1. Brazil, Ministry of Health. Routine manual for stroke care. Brasília-DF. 2013. World Health Organization. World Health Statistics 2022: Monitoring Health for the SDGs. Geneva: WHO; 2022.
2. Monteiro WA, et al. The importance of early mobilization in prior stroke: a literature review. Rev Eletr Acervo Médico. 2022;8:e9921.
3. Sociedade Brasileira de AVC. Stroke statistics in Brazil and the World. DATASUS. Available from: http://tabnet.datasus.gov.br. Accessed: Oct 20, 2022. Shumway-Cook A, Woollacott M. Motor control: theories and practical applications. 3rd ed. São Paulo: Manole; 2010.
4. Sebastián-Romagosa M, et al. Brain-computer interface treatment for upper extremity motor rehabilitation in stroke patients—a feasibility study. Front Neurosci. 2020;14:591435.
5. Lotte F, Larrue F, Mühl C. Flaws in current human training protocols for spontaneous BCIs: lessons from instruction-based paradigms. Front Hum Neurosci. 2013;7:52.
6. Guo Y, Gu X, Yang GZ. Human–Robot Interaction for Rehabilitation Robotics. In: Digitalization in Healthcare. 2021. p. 269-295.
7. Lundy-Ekman L. Neuroplasticity. In: Shumway-Cook A, Woollacott MH. Physiology of Motor Control. Manole; 2007.
8. Maclean N, Pound P. A critical review of the concept of patient motivation in physical rehabilitation. Soc Sci Med. [no date].
9. Hackett ML, Pickles K. Post-stroke depression: Part 1. Lancet Neurol. 2014;13(8):816-26.
10. Yoshida T, et al. Motivation for rehabilitation in subacute stroke patients: a qualitative study. Front Rehabil Sci. 2021;2.