



## Exploring Stroke Survivors' Experiences with Non-Invasive Neurostimulation Rehabilitation

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### ABSTRACT

Stroke rehabilitation represents a critical area in biomedical engineering, where innovative medical technologies aim to improve functional recovery and quality of life. Within this field, non-invasive neurostimulation has emerged as a promising technique, yet little is known about how patients subjectively experience and interpret this therapy. Despite increasing clinical evidence on its physiological efficacy, prior research has largely overlooked patients' lived perspectives, creating a gap in understanding the experiential dimension of neurostimulation. The knowledge gap lies in the lack of understanding of the lived meanings attached to neurostimulation, raising the question of how stroke survivors perceive its benefits, challenges, and integration into their daily lives. This study uniquely addresses that gap by exploring the phenomenological meanings of neurostimulation from the patients' standpoint, highlighting the humanistic aspects often absent in biomedical discussions. Here we show, through a hermeneutic phenomenological approach using in-depth interviews and interpretative phenomenological analysis, that patients interpret neurostimulation not only as a clinical intervention but also as a personal and social experience. Data were collected from twelve stroke survivors who underwent multiple sessions of non-invasive neurostimulation, and the analysis identified four overarching themes: negotiating comfort and discomfort, redefining agency, navigating social and emotional dimensions, and balancing expectations with uncertainty. The findings revealed that patients experienced the therapy as a journey marked by ambivalence, where hope and empowerment coexisted with dependency and skepticism. These insights extend existing literature by illuminating how rehabilitation is experienced as a dynamic negotiation between body, identity, and social context—dimensions that quantitative studies rarely capture. The study demonstrates that incorporating phenomenological insights into clinical practice enriches our understanding of patient-centered rehabilitation and underscores the need for future research to integrate subjective experience with biomedical innovation. By articulating this experiential layer, the study contributes a novel interpretive framework for bridging human experience with technological advancement in stroke rehabilitation.



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### INTRODUCTION

Stroke remains one of the leading causes of long-term disability worldwide, profoundly altering the physical, emotional, and social dimensions of survivors' lives (Aam et al., 2020). Beyond the measurable neurological deficits, individuals often face an enduring disruption of daily routines, personal identity, and social participation. In many cultural contexts, recovery from stroke is not perceived solely as a medical process but also as a deeply personal journey shaped by the interplay of hope, resilience, and vulnerability within family and community life (Ambrosini et al., 2021).

In recent decades, advances in biomedical engineering have introduced innovative rehabilitation strategies, including the use of non-invasive neurostimulation techniques (Ambrosini et al., 2020). While these devices are designed to enhance motor recovery and improve functional outcomes, their adoption extends beyond the technical efficacy of the intervention. For patients, the

therapy becomes embedded in lived experience—colored by perceptions of bodily sensations, trust in technology, and emotional responses to recovery trajectories (Aprile et al., 2020). Such experiences are situated in broader socio-cultural frames, where attitudes toward disability, technology, and health care profoundly influence acceptance and engagement.

Despite increasing attention to clinical outcomes, relatively little emphasis has been placed on understanding how patients themselves interpret and give meaning to these therapeutic encounters (Mukhlis et al. 2023). The subjective dimension of rehabilitation—the feelings of uncertainty, empowerment, dependency, or stigma—remains underexplored, even though these experiences are critical in shaping adherence and long-term engagement with therapy (Baker et al., 2023). Capturing these perspectives requires an approach that privileges the voice of patients and situates their narratives within the context of lived reality.

This need underscores the importance of phenomenology, which focuses on uncovering the essence of human experiences as they are lived (Beghi et al., 2021). By examining how individuals articulate and make sense of their rehabilitation journeys, phenomenological inquiry provides access to meanings that extend beyond clinical metrics (Boyne et al., 2023). Such an approach is essential for developing a more holistic understanding of recovery after stroke—one that integrates technological advancement with the experiential realities of patients.

Building on the growing recognition of rehabilitation as a lived experience, research exploring patients' subjective encounters with medical technologies has become increasingly important (Mukhlis & Saidah, 2025). Phenomenological inquiry has been applied to capture these dimensions, offering valuable insights into how individuals construct meaning around therapeutic interventions and their integration into daily life. Studies of stroke survivors, for example, have illuminated the nuanced ways patients interpret the benefits and limitations of rehabilitation technologies, revealing perspectives that would remain invisible through quantitative assessments alone (Chae et al., 2020).

Nevertheless, methodological challenges persist in accessing the depth of lived experience. Many prior investigations have relied heavily on clinical metrics, structured surveys, or randomized controlled trials, which privilege measurable outcomes while overlooking the interpretive and emotional landscapes of patients (Chapman et al., 2021). Such approaches, while indispensable for establishing efficacy, are limited in their capacity to capture the complexity of human meaning-making (Mukhlis, 2025). Even when qualitative components are included, they often remain secondary to clinical endpoints, leaving the phenomenological richness of participants' voices underexplored.

These limitations render previous methods insufficient for comprehensively understanding the essence of patient experiences with neurostimulation in stroke rehabilitation (Chatterjee et al., 2022). Without direct engagement with the narratives and meaning structures of participants, critical insights into motivation, adherence, and acceptance of innovative therapies remain absent (Chen et al., 2021). As a result, phenomenological research holds a distinct and necessary role in filling this gap, offering a methodological pathway to uncover the subjective realities that shape recovery trajectories.

Current approaches to post-stroke rehabilitation with neurostimulation devices have predominantly relied on clinical trials, quantitative outcome measures, and structured evaluations (Mukhlis & Abdullah, 2025). These strategies have provided valuable evidence of efficacy and safety, offering practical solutions for improving motor recovery. However, such approaches remain insufficient for addressing how patients themselves experience these interventions in their daily lives (de Luca et al., 2020). The emphasis on quantifiable improvements often obscures the nuanced meanings that patients attribute to therapy—meanings that shape their willingness to engage, their perception of progress, and their long-term adherence to treatment.

The limitation of existing methods lies in their inability to capture the richness of subjective experience. By focusing narrowly on biomedical outcomes, prior research has overlooked the emotional, psychological, and social dimensions of recovery (Deyhoul et al., 2020). This has resulted in a fragmented understanding of rehabilitation, where clinical success may not align with patients'

lived realities (Gjellesvik et al., 2021). For instance, discomfort, stigma, or feelings of dependency may undermine adherence, even in cases where measurable improvements are observed.

Addressing this gap requires a methodological shift toward phenomenological inquiry, which prioritizes the exploration of lived experience and the meanings embedded within it (Grau-Pellicer et al., 2020). Through this approach, it becomes possible to uncover the essence of how patients interpret neurostimulation as part of their recovery journey, and how such interpretations influence acceptance and integration of medical technology into daily practice (Mukhlis et al. 2025). Phenomenology thus offers a holistic alternative, providing insights that extend beyond clinical endpoints to reveal the human dimension of rehabilitation.

Previous studies have highlighted the importance of understanding how patients make sense of their rehabilitation experiences, particularly in relation to the use of innovative medical technologies. Research on stroke survivors has shown that while neurostimulation can support motor recovery, the subjective dimension of treatment is often neglected in clinical studies (Hall et al., 2020). Theories of lived experience suggest that recovery is not only a biological process but also a personal and social journey shaped by meaning. Earlier qualitative work has indicated the presence of fear, hope, and ambivalence, yet these findings remain partial and fragmented (Harari et al., 2020). Thus, there is still a need for deeper exploration into how patients interpret and integrate these therapies into their lives.

To address this gap, a phenomenological approach was adopted with a hermeneutic orientation based on Heidegger's perspective. This method was chosen because it allows for the uncovering of meanings within patients' narratives and highlights the ways in which personal, social, and cultural contexts shape their experiences (Mukhlis, Janwari, et al., 2023). The approach seeks to answer the question of how stroke survivors interpret the benefits, challenges, and uncertainties of neurostimulation therapy (Lambelet et al., 2020). Through in-depth interviews and interpretative phenomenological analysis, the study captures the richness of lived experiences that are often absent in quantitative research. The use of phenomenology provides a more holistic understanding of rehabilitation as both a clinical and existential process.

The structure of this article reflects this orientation and proceeds in a systematic manner. The introduction situates the study within the broader field of biomedical innovation and outlines the theoretical and methodological background. The method section presents the phenomenological design, participant selection, data collection, and analytic process. The results section organizes the findings into key themes supported by narrative accounts and direct quotations. Finally, the discussion interprets the significance of these findings within the wider literature and concludes by addressing their implications for practice and future research.

## **RESEARCH METHODS**

### **Study Design**

A phenomenological research design was employed to explore the lived experiences of stroke survivors undergoing rehabilitation with non-invasive neurostimulation devices (J. Lee & Stone, 2020). Phenomenology was chosen because it allows for an in-depth understanding of subjective meanings and perceptions that cannot be fully captured by quantitative approaches. This design emphasizes how individuals experience and interpret their reality, providing insights into the essence of the phenomenon under study. The study was guided by a hermeneutic phenomenological approach, drawing upon Heidegger's perspective, which focuses on the interpretation of lived experiences within social and cultural contexts. This orientation enabled a deeper examination of how participants make sense of their rehabilitation process through the use of advanced medical technology.

### **Participants**

Participants consisted of adult stroke survivors who had undergone rehabilitation with non-invasive neurostimulation techniques, such as transcranial direct current stimulation (tDCS) or functional electrical stimulation (FES) (J. J. Lee et al., 2021). Purposive sampling was applied to

ensure that participants possessed direct experience relevant to the research focus. Inclusion criteria required participants to be adults aged 40–75 years, diagnosed with post-stroke motor impairments, and having completed at least four sessions of neurostimulation therapy. Individuals with severe cognitive impairment or inability to communicate verbally were excluded to maintain the integrity of data collection. The final group comprised 12 participants (7 males and 5 females), with an average age of 59.8 years. Demographic variations, such as marital status, education level, and socioeconomic background, were noted to provide contextual understanding of the phenomenon.

### **Data Collection**

Data were collected through semi-structured, in-depth interviews designed to elicit rich descriptions of participants' subjective experiences. An interview guide with open-ended questions was utilized, enabling participants to freely narrate their perceptions, challenges, and expectations regarding neurostimulation therapy (Li et al., 2021). Interviews were conducted face-to-face in a quiet rehabilitation facility room to ensure privacy and comfort. Each session lasted between 45 and 70 minutes and was audio-recorded with participants' consent. Field notes and reflective memos were also documented to capture non-verbal cues and contextual nuances. To encourage open dialogue, participants were assured that there were no right or wrong answers and that their perspectives were valued.

### **Data Analysis**

Data were analyzed using Interpretative Phenomenological Analysis (IPA), which focuses on identifying patterns of meaning within participants' narratives. The process began with verbatim transcription of interview recordings, followed by repeated readings to gain familiarity with the data. Texts were segmented into meaning units, which were then coded and grouped into emergent categories (Lieshout et al., 2020). These categories were further clustered into overarching themes that reflected the essence of participants' lived experiences. Reductive and interpretive techniques were applied iteratively to move beyond surface descriptions toward deeper conceptual insights. NVivo software supported data organization and coding, although the interpretive process remained central to the analysis. The final thematic structure captured both shared and divergent perspectives across participants, allowing for a nuanced synthesis of findings.

## **RESULTS**

### **Negotiating Comfort and Discomfort During Therapy**

Participants consistently described their experiences with non-invasive neurostimulation as a process of negotiating between comfort and discomfort. While some participants highlighted moments of relief and improvement in motor control, others recounted sensations of unease, tingling, or transient headaches. One participant explained:

“At first, I was nervous when the device was turned on. I could feel a strange tingling in my head, and I worried if it was safe. But after several sessions, I started to accept it and even felt hopeful that it might help me walk again.”

This theme reflects how patients balance initial apprehension with gradual acceptance, situating their bodily sensations within their broader desire for recovery. The embodied perception of the therapy was not merely physiological but shaped by emotional states such as fear, hope, and uncertainty.

Beyond these personal accounts, the analysis suggests that comfort and discomfort operate as dynamic metaphors for patients' adaptation to technological intervention—representing both physical sensations and psychological negotiations of trust toward medical innovation. The movement from fear to acceptance illustrates a re-embodiment process where patients reinterpret their bodies as sites of both vulnerability and transformation.

### **Redefining Agency and Control in Rehabilitation**

Many participants interpreted neurostimulation as an intervention that reshaped their sense of agency during rehabilitation. Some described the device as a supportive partner in regaining control over their body, while others felt dependent on external technology for progress. A participant reflected:

“It was not me moving my hand—it felt like the machine was helping me. At first, I didn’t like that because I wanted to recover by myself. But later, I realized that with the device, I could do more than without it.”

This theme highlights the ambivalence between empowerment and dependency. For some, neurostimulation reinforced their motivation; for others, it raised existential concerns about autonomy and reliance on external aids.

Interpretively, this tension reveals a deeper reconfiguration of self-agency in technologically mediated healing. Patients’ shifting perceptions—from resistance to acceptance—signal a transformation in how control is conceptualized: not as pure independence but as a shared agency between human intention and technological facilitation. Such findings nuance conventional rehabilitation models by emphasizing the relational dimension of agency, rather than viewing it as an isolated individual capacity.

### Neurostimulation and Self-Agency



### Navigating Social and Emotional Dimensions of Therapy

Beyond the clinical encounter, participants emphasized the social and emotional impact of using neurostimulation devices. Feelings of stigma, curiosity from family members, or support from caregivers shaped how patients integrated the therapy into their daily lives. One participant stated:

“My family kept asking me about the helmet I was wearing. I felt embarrassed at first, but later it became a conversation that brought us closer. They encouraged me, and that made the therapy easier to continue.”

These narratives illustrate that the therapy was experienced not only as an individual medical intervention but also as a socially embedded phenomenon, interwoven with familial relationships, cultural perceptions, and emotional resilience.

Deeper analysis reveals that neurostimulation became a social catalyst, reconfiguring interpersonal dynamics within the home and community. The emotional responses—ranging from shame to pride—reflect broader cultural meanings attached to visible medical technologies. This suggests that rehabilitation outcomes are co-constructed through social recognition and emotional validation, extending far beyond the confines of clinical efficacy.

### Balancing Expectations and Uncertainty of Outcomes

Participants often negotiated between optimism and skepticism regarding the long-term benefits of neurostimulation. Some expressed high expectations for recovery, while others questioned the effectiveness of the device. One participant explained:

“I hoped this machine would make me walk again, but the progress was slow. Sometimes I doubted if it was working at all, but I kept going because the doctors believed in it.”

This theme underscores the tension between medical promises and patient expectations, where hope becomes both a motivating and potentially frustrating force. The uncertainty of outcomes highlights the importance of aligning clinical communication with patients’ lived experiences.

The interpretive synthesis indicates that uncertainty itself becomes a productive emotional space in the rehabilitation journey—sustaining hope while prompting critical reflection on biomedical narratives of progress. This ambivalence shows that patients actively reconstruct meaning in the face of unpredictability, negotiating between evidence-based optimism and personal doubt. Consequently, hope emerges not merely as emotional endurance but as an adaptive cognitive strategy that sustains engagement with therapy despite ambiguous results.

## **DISCUSSION**

This study revealed that stroke survivors experienced neurostimulation therapy as a process marked by ambivalence, oscillating between hope and uncertainty, comfort and discomfort, empowerment and dependency (Alec-Mihai et al., 2024). These findings directly address the central research question by showing that rehabilitation with neurostimulation is not only a biomedical intervention but also a deeply personal and existential journey.

### **Contribution of Findings to the Research Question**

The findings contribute to the central question by highlighting how patients actively interpret and negotiate their engagement with neurostimulation therapy (Bernardi et al., 2021). Rather than being passive recipients of medical treatment, participants constructed meaning from their embodied sensations, emotional responses, and social interactions surrounding therapy. This interpretation shaped their sense of agency, their motivation to persist, and their willingness to integrate technology into daily life. Such insights demonstrate that the success of neurostimulation cannot be measured solely by clinical outcomes; it must also be evaluated in terms of how patients perceive and accept the intervention as part of their recovery (Mukhlis, 2025a). The study therefore provides a unique contribution by foregrounding patients’ voices, revealing that their lived experiences are essential to understanding adherence, satisfaction, and the long-term viability of medical innovations.

### **Relation to Previous Literature and Theoretical Perspectives**

These results resonate with earlier phenomenological investigations that underscored the complexity of patients’ experiences with rehabilitation technologies (Boissonnault et al., 2021). Consistent with Costescu et al. (2024), participants in this study expressed both optimism and hesitation, suggesting that the psychological and social dimensions of therapy are inseparable from its clinical application. At the same time, this study extends prior findings by showing how experiences of agency and dependency emerge simultaneously, a dynamic not fully explored in earlier accounts (Mukhlis, Arifin, Ridwan, Zulbaidah, et al., 2025). The themes of stigma, support, and relational meaning identified here echo broader phenomenological theories of embodiment and intersubjectivity, which argue that healing and adaptation are shaped as much by social contexts as by biological processes. By connecting these insights to established frameworks, this research demonstrates that phenomenology offers a vital complement to quantitative studies, filling the gap between clinical efficacy and lived reality.

### **Implications of the Findings**

The findings of this study have important implications for clinical practice, social understanding, and the broader field of biomedical innovation. By highlighting the ambivalent ways in which patients negotiate comfort, agency, and social acceptance, the results suggest that rehabilitation programs should not only focus on the physiological outcomes of neurostimulation but also on the subjective meanings attached to therapy (D’Arcy et al., 2020). Clinicians may need to incorporate patient narratives into the design of rehabilitation plans, ensuring that treatment aligns with the emotional and cultural realities of survivors. On a professional level, the study underscores

the necessity of integrating phenomenological insights into medical training, equipping healthcare providers with the capacity to recognize and respond to patients' lived experiences (Di Filippo et al., 2025). More broadly, these findings point to the value of adopting patient-centered approaches that respect the complexity of recovery, thereby enhancing adherence and long-term integration of medical technologies.

### **Study Limitations**

Several limitations should be acknowledged when interpreting these findings. The study involved a relatively small group of participants from a specific cultural and clinical context, which may restrict the transferability of results to other populations (Mukhlis, Maryam, et al., 2023). The use of purposive sampling, while appropriate for phenomenological inquiry, may also have introduced a bias toward individuals who were more willing or able to articulate their experiences. Furthermore, the reliance on self-reported data through interviews may limit the depth of understanding in areas where participants found it difficult to verbalize complex emotions or embodied sensations (Fedotchev et al., 2023). These limitations do not diminish the value of the findings but rather highlight the need for cautious interpretation and further exploration across diverse contexts.

### **Directions for Future Research**

The insights generated here open several avenues for future inquiry. Subsequent studies could expand the scope by including larger and more culturally diverse groups of participants to explore how different social contexts influence the meanings attached to neurostimulation therapy (Fickling et al., 2020). Longitudinal designs may also be beneficial in examining how patients' interpretations of therapy evolve over time, particularly in relation to motivation, adherence, and reintegration into daily life. Additionally, interdisciplinary approaches that combine phenomenology with complementary frameworks—such as sociology of technology or narrative medicine—could deepen our understanding of the intersection between innovation and lived experience (Mukhlis et al., 2024). By pursuing these directions, future research can continue to bridge the gap between clinical efficacy and human experience, contributing to a more comprehensive vision of rehabilitation after stroke.

## **CONCLUSION**

This study explored the lived experiences of stroke survivors undergoing rehabilitation with non-invasive neurostimulation devices, addressing the lack of attention to subjective perspectives in prior research. The findings revealed that patients navigated their therapy through complex tensions of comfort and discomfort, empowerment and dependency, as well as hope and uncertainty. These insights demonstrate that clinical success alone does not define effective rehabilitation, since acceptance and adherence are also shaped by personal meaning and social context. By highlighting these dimensions, the study fills an important gap in the literature and provides a richer understanding of how neurostimulation is integrated into patients' recovery journeys. The results further emphasize the value of phenomenology in uncovering the depth of human experience and informing patient-centered care.

Beyond theoretical contributions, the findings carry several practical implications for clinical practice and policy. Clinicians should consider incorporating psychosocial assessment and dialogue about patient perceptions as part of neurostimulation protocols, ensuring that emotional comfort and sense of agency are actively monitored alongside physical outcomes. Interdisciplinary rehabilitation teams—combining neurologists, physiotherapists, and psychologists—can foster more holistic approaches that respond to patients' embodied and emotional needs. At the policy level, integrating patient experience metrics into rehabilitation evaluation frameworks could enhance the quality and sustainability of neurostimulation programs, promoting more human-centered innovation in healthcare systems. Future research may expand these findings by including more diverse populations and longitudinal approaches to explore how meanings evolve over time. Such studies would not only deepen conceptual understanding but also guide the development of evidence-based guidelines that balance technological efficacy with experiential well-being.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

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