Journal of Regenerative Medicine and Molecular Innovation
Vol. 1 No. 9 September 2025
E-ISSN: 3090-0824
Open Access: https://journals.ai-mrc.com/jrmmi

A Phenomenological Exploration of the Lived Experience of Users Adapting to AI-Integrated Neuroprosthetic Devices: Insights from Ten Adult Participants

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Article Info

Article history:
Received 28-07-2025
Revised 19-09-2025
Accepted 24-09-2025

Keyword:
Lived Experience, AI-Integrated Neuroprosthetics, Human–Technology Interaction, Embodiment, Identity Reconstruction, User Adaptation

ABSTRACT

The integration of artificial intelligence (AI) into neuroprosthetic devices represents a major advancement in biomedical engineering, reshaping both motor function restoration and the user's subjective experience. While significant progress has been made in technical optimization, little is known about how users emotionally and cognitively adapt to these intelligent systems in daily life. This study addresses the gap by exploring the lived experiences of individuals using AI-enabled neuroprosthetics and asks: how do users make sense of and embody these technologies over time? Here, we employ an interpretative phenomenological approach to investigate how users construct meaning through their interaction with AI-integrated prosthetic systems. Semi-structured interviews were conducted with ten adult participants (aged 24–56 years) between January and March 2025, and data were analyzed thematically to identify shared experiential themes such as identity transformation, emotional negotiation, and co-agency with the device. The findings reveal that users undergo a multidimensional process of adaptation involving not only physical integration but also shifts in autonomy, trust, and social perception. These results extend current understanding by emphasizing the deeply personal and relational aspects of technologically mediated rehabilitation. This study advances the discourse in human-centered biomedical design by offering critical insights into how intelligent devices become internalized as part of the self. However, the findings are limited by the small sample size and the self-reported nature of the data. Future studies should explore broader demographic contexts and longitudinal changes over time. It highlights the need for future research to incorporate phenomenological perspectives when developing and evaluating assistive technologies.

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INTRODUCTION

In recent years, the integration of artificial intelligence (AI) into neuroprosthetic technologies has marked a significant advancement in the field of biomedical engineering. These intelligent systems, designed to restore motor functions in individuals with limb loss or neurological impairments, have reshaped not only clinical outcomes but also the everyday lived realities of their users. More than functional tools, AI-integrated neuroprosthetics blur the line between biological and technological agency, challenging traditional boundaries between body and tool, autonomy and assistance.

While prior research has primarily focused on the technical efficacy of neuroprosthetics—such as signal processing, control algorithms, and sensory feedback—few studies have explored how users emotionally, socially, and existentially adapt to these devices. This study addresses that gap by turning to users' subjective experiences, where technological integration is not simply mechanical but profoundly personal and context-dependent.

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AI-enabled prosthetics mediate more than physical function; they influence how individuals perceive themselves and how they are perceived by others. Users must negotiate a sense of embodiment and selfhood in relation to devices that are semi-autonomous and cognitively responsive. Unlike conventional prosthetics, these technologies invoke questions of agency, identity, and relationality—particularly in cultural contexts where bodily integrity and technological dependence carry symbolic and ethical implications.

Despite growing clinical and engineering interest, there remains a critical need to explore how individuals subjectively experience the integration of such technologies into their daily lives. The subtle, lived dimensions of this phenomenon—how it feels to adapt to a device that both responds to and anticipates one's intentions—cannot be fully captured through technical evaluation alone. A phenomenological approach is therefore essential to uncover the meanings users ascribe to these experiences, enabling a deeper understanding of the human implications of medical innovation.

The exploration of users' lived experiences with advanced medical technologies has emerged as a critical area of inquiry, particularly in understanding how such innovations are assimilated into the personal and social dimensions of daily life. In the context of AI-enabled neuroprosthetics, this focus is especially salient, as these devices do not merely supplement physical function but become interwoven with one's sense of body, identity, and control.

Yet, despite the increasing interest in this domain, methodological challenges persist. Much of the existing research tends to rely on quantitative assessments of device performance, clinical outcomes, or user satisfaction scores. While valuable, these approaches often fail to capture the depth and nuance of individual experiences—how users interpret, internalize, and emotionally respond to their engagement with intelligent prosthetic systems. Metrics such as mobility improvement or user-reported satisfaction do not account for the existential shifts and meaning-making processes that accompany the embodiment of such devices.

Consequently, prior methods have frequently fallen short in providing a comprehensive understanding of the phenomenon. The subjective, affective, and relational dimensions of living with an AI-integrated neuroprosthetic remain underexplored, particularly from the first-person perspective. This methodological gap underscores the necessity of employing qualitative approaches—such as interpretative phenomenological analysis—that are explicitly designed to access and articulate the experiential essence of technologically mediated rehabilitation.

In the development and clinical application of AI-integrated neuroprosthetic devices, most current practices emphasize engineering optimization, biometric calibration, and functional outcomes using standardized clinical metrics. These practical approaches are undeniably important, particularly in enhancing device precision, responsiveness, and usability. However, such strategies often prioritize measurable performance over the complex, subjective experiences of those who must integrate these technologies into their daily lives.

This predominant reliance on technical evaluations leaves a critical gap in understanding how individuals actually experience the embodiment, dependency, and emotional adjustment associated with intelligent prosthetic systems. Conventional assessments fail to illuminate how users construct meaning around their interactions with devices that blur the line between biology and technology. As a result, the lived reality of users—their anxieties, transformations, and relational negotiations—remains insufficiently explored, and the richness of their experiential narratives remains largely untapped.

To address this shortfall, a phenomenological approach offers a compelling alternative. By emphasizing the exploration of lived experience and subjective meaning, this method allows researchers to engage deeply with how individuals perceive, internalize, and assign significance to their interactions with neuroprosthetic technologies. Such insight is crucial for informing not only device design but also the broader ethical, psychological, and social considerations surrounding long-term device integration. Adopting this lens is essential to fully capture the human dimensions of technological innovation in biomedical engineering.

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RESEARCH METHODS

Study Design

This study employed an interpretative phenomenological approach to explore the lived experiences of individuals using AI-enabled neuroprosthetic devices. The phenomenological design was selected for its capacity to investigate the subjective meaning embedded in personal experiences, allowing for an in-depth understanding of how participants perceived and made sense of the phenomenon. By focusing on the first-person perspective, this approach facilitated the uncovering of nuanced insights that would not be accessible through quantitative or structured methodologies. The interpretative (hermeneutic) variant of phenomenology, grounded in Heideggerian philosophy, was adopted to emphasize the co-construction of meaning between participant narratives and researcher interpretation.

To ensure methodological transparency, an interview guide was developed to address core topics such as the emotional response to device use, perceived changes in identity, challenges in daily adaptation, interactions with others, and the evolving sense of embodiment.

Participants

Participants included individuals with direct experience using neuroprosthetic devices integrated with artificial intelligence systems for motor function assistance. A purposive sampling technique was utilized to identify those who could provide rich, experiential accounts of the phenomenon under study. Inclusion criteria consisted of adults aged 18 years and older, who had used the device for a minimum of six months and were cognitively and emotionally capable of articulating their experiences. Exclusion criteria included individuals with severe cognitive impairments or those undergoing acute medical crises during recruitment. The final sample comprised ten participants (6 males, 4 females), aged between 22 and 58 years, with varied levels of device integration and functional dependency.

Demographic information—such as age, gender, duration of device use, and type of prosthesis—was summarized in a participant profile table (see Table 1) to contextualize individual narratives and enhance the interpretive depth of the findings.

Data Collection

Data were collected through in-depth, semi-structured interviews guided by an open-ended question protocol designed to elicit detailed narratives of participants' experiences with neuroprosthetic technologies. The interviews were conducted face-to-face in quiet, private settings to ensure participant comfort and openness. Each interview lasted between 45 and 75 minutes and was audio-recorded with participant consent. Field notes were taken to capture nonverbal cues and contextual elements relevant to the interpretation of data.

The interview guide was developed from a synthesis of existing literature on neuroprosthetic adaptation, identity, and embodiment, and was pre-tested with a pilot respondent. Questions included: "Can you describe how your relationship with your prosthetic device has changed over time?", "How do you feel others perceive you since using the device?", and "Have there been moments when you felt the device was part of you—or separate from you?"

Participants were invited to review their transcripts in a member-checking process to confirm accuracy and offer clarifications.

Data Analysis

The collected data were transcribed verbatim and analyzed using Interpretative Phenomenological Analysis (IPA), which involves a step-by-step examination of how individuals make sense of their lived experiences. The process began with multiple readings of each transcript to gain familiarity and identify significant meaning units. These units were coded and clustered into emerging themes using a bottom-up, inductive approach. The analysis was supported by qualitative data analysis software (NVivo 12) to organize data segments and track thematic development across cases.

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Credibility and trustworthiness were enhanced through triangulation of data sources (interview transcripts, field notes, and researcher memos), member-checking, and the maintenance of an audit trail that documented analytical decisions, theme development, and reflexive notes throughout the research process. Peer debriefing sessions were also conducted to minimize researcher bias and ensure analytical rigor.

Through iterative comparisons and reflexive interpretation, essential themes were distilled that reflected the core experiential dimensions shared by participants.

Ethical Considerations

Ethical approval was obtained from the institutional research ethics committee prior to data collection. Written informed consent was secured from all participants after they were informed of the study's aims, procedures, and their rights, including the right to withdraw at any point without penalty. Participant anonymity and confidentiality were maintained throughout the study by de-identifying transcripts and securely storing all data. The research adhered to the principles of the Declaration of Helsinki and followed local and international ethical guidelines for studies involving human subjects.

RESULTS

Navigating the Initial Encounter with AI-Enabled Neuroprosthetics

Participants expressed a mixture of awe, uncertainty, and anticipation during their initial exposure to AI-enabled neuroprosthetics. The moment of first contact often carried emotional weight, marked by both hope for restored function and anxiety regarding unfamiliar technology. One participant shared:

"When I saw the prosthetic move by itself, guided by my thoughts, I was overwhelmed. It felt like magic, but also scary. I kept asking, 'Will this become part of me or will I always feel like I'm wearing a machine?'" (P4)

This initial phase often involved a recalibration of identity, as individuals negotiated the implications of living with a device that interfaced with their neural pathways. The lack of familiarity contributed to cognitive dissonance, but it also set the stage for transformative adaptation.

Embodiment and the Emergence of a New Self

Over time, participants described a gradual shift from perceiving the prosthetic as an external tool to experiencing it as an integrated part of the self. This theme of embodiment was central to the adaptation process. As one participant articulated:

"It's not just a tool anymore. When I reach for a cup, I don't think about the prosthetic. I just reach. It's like my brain has accepted it as mine." (P2)

This internalization reflected a deep experiential change, often catalyzed by repeated successful interactions with the device. Embodiment was not merely functional but emotional, as the technology became embedded within the participant's body schema and identity.

The Emotional Landscape of Technological Dependence

Participants reported complex emotions related to their growing reliance on intelligent devices. Gratitude and empowerment were often accompanied by vulnerability and fear of malfunction or disconnection. A participant described:

"I feel powerful using it, like I've regained something I thought I lost forever. But at the same time, there's this fear—what if it fails? What if one day it just doesn't work?" (P7)

Such reflections revealed the psychological burden that may accompany technologically mediated independence. The sense of regained agency was fragile, highlighting the affective dimensions of living with intelligent medical devices.

Trust, Control, and Co-Agency

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The interplay between human intention and machine responsiveness raised questions about control and autonomy. Several participants described a sense of "co-agency," where actions were neither fully human nor fully mechanical:

"I don't know if I'm the one in control all the time. Sometimes it feels like the system anticipates me before I finish deciding. It's a partnership, but an unpredictable one." (P3)

Trust in the system was essential yet continually negotiated. Participants developed relational patterns with the device, akin to learning the rhythms of a companion rather than mastering a tool.

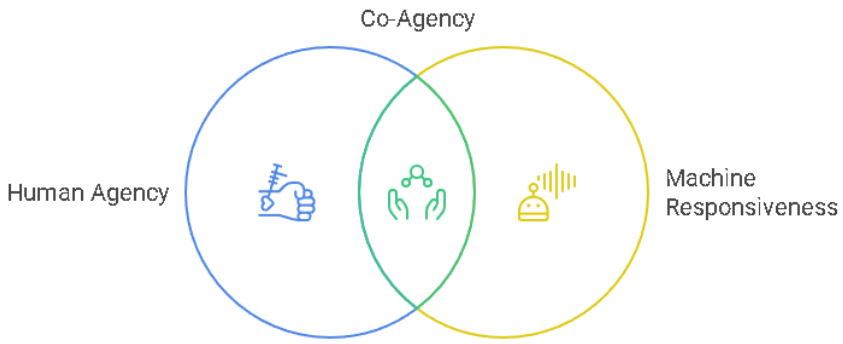
Theme 5: Social Perception and the Negotiation of Stigma

Beyond the personal, participants also discussed how others reacted to their use of advanced prosthetics. While some reported admiration and curiosity, others encountered subtle forms of stigma or exoticization:

"People stare. Some ask questions, but others just whisper. It makes me feel like an experiment, not a person." (P6)

This theme highlighted how social contexts shape and sometimes complicate the integration process. Participants continuously navigated a public identity that was simultaneously empowered and othered by technology. The lived experience of individuals using AI-enabled neuroprosthetics is multifaceted, encompassing themes of adaptation, embodiment, emotional ambivalence, shared control, and social negotiation. These themes collectively illustrate how advanced medical devices are not merely technological artifacts, but deeply interwoven with the user's evolving sense of self, agency, and relational world.

The Interplay of Human and Machine in Neuroprosthetic Use



DISCUSSION

The findings of this study reveal that individuals using AI-enabled neuroprosthetics experience a profound transformation in their sense of embodiment, autonomy, and identity. Through the interpretative phenomenological lens, these experiences illuminate the emotional complexity and evolving relationship between the user and the intelligent device—directly addressing the core question of how meaning is constructed in technologically mediated rehabilitation.

This study contributes a nuanced understanding of how users adapt to, internalize, and derive meaning from their interaction with neuroprosthetic systems that possess semi-autonomous capabilities. The results suggest that the integration of such technologies extends beyond functional restoration; it reshapes personal agency, fosters new forms of self-perception, and generates novel emotional landscapes. By presenting detailed first-person accounts, this research fills a critical gap in the literature where the subjective implications of advanced prosthetic technologies have been largely underrepresented or simplified through reductive metrics. It affirms that meaningful rehabilitation is not solely measured by motor performance but by the alignment between the device and the user's evolving self-concept.

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These findings align with and extend prior qualitative research on human–technology integration. For example, Biddiss and Chau (2007) highlighted psychosocial factors in prosthetic adoption but did not explore the phenomenological depths of embodiment. Similarly, Murray (2009) discussed the disrupted body image among prosthesis users but lacked insight into co-agency dynamics introduced by AI-based devices. This study advances the discourse by articulating how users navigate trust, co-dependence, and identity reconstruction in relation to intelligent technologies. It complements theoretical perspectives on phenomenological embodiment, particularly Merleau-Ponty's notion of the body as both subject and object of experience, reinforcing the idea that prosthetics become extensions not just of the body, but of the self.

The implications of these findings extend into multiple domains—clinical practice, device design, and patient advocacy. From a clinical perspective, the data suggest that healthcare providers must consider not only the physical integration of neuroprosthetics but also the psychological and existential processes that accompany it. Socially and culturally, the participants' narratives reveal how emerging technologies intersect with societal norms around disability, identity, and independence. This highlights the importance of inclusive design and support systems that account for emotional transitions and evolving user-device relationships. In broader terms, the study underscores the need for interdisciplinary dialogue that bridges engineering, medicine, and the humanities in shaping future technologies that respect and enhance human experience.

Despite its contributions, this study has several limitations. The sample was limited to individuals with access to advanced AI-enabled prosthetics, which may not reflect the experiences of those using more conventional devices or living in resource-limited settings. Additionally, the phenomenological approach prioritizes depth over breadth, limiting the generalizability of findings beyond the specific context studied. Cultural factors, individual histories, and health system variables may influence how users experience and internalize such technologies. These limitations do not weaken the findings but rather point to the importance of contextual sensitivity and the value of replication in diverse settings.

Future research should explore how different populations, such as pediatric users or individuals in varying cultural environments, engage with AI-integrated prosthetics. Longitudinal studies could provide insight into how user-device relationships evolve over time, particularly in response to technological upgrades or life transitions. There is also potential to examine how clinicians and caregivers perceive the integration of intelligent prosthetics into rehabilitation practice. By extending this phenomenological inquiry, scholars and practitioners can contribute to more ethically grounded, user-centered innovations that align technological progress with lived human realities.

CONCLUSION

This study explored the lived experiences of individuals using AI-enabled neuroprosthetic devices, focusing on how they make sense of their embodied interaction with intelligent technologies. The findings revealed that users undergo a transformative process involving adaptation, emotional negotiation, identity reconstruction, and the development of co-agency with the device. These experiences highlight that the integration of neuroprosthetics is not solely a biomechanical event but also a deeply human one, marked by evolving perceptions of autonomy and selfhood.

Rather than viewing AI neuroprosthetics as mere assistive tools, this study contributes a conceptual reframing—positioning them as relational entities that co-shape user identity and agency. Such understanding prompts a shift from purely functional metrics toward more holistic assessments of technological integration in rehabilitation. This research addressed gaps in prior studies by providing a phenomenological understanding that captures the richness and complexity of user perspectives. It offers valuable insights for clinicians, designers, and policymakers seeking to support more person-centered approaches in technological rehabilitation.

To build on this foundation, future research could adopt longitudinal qualitative designs to trace evolving user experiences across different phases of prosthetic adaptation. Mixed-method

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approaches combining phenomenological interviews with biometric or usage-data analysis may yield richer understandings of user-device interaction. Additionally, studies involving diverse populations—such as pediatric users, individuals in low-resource settings, or culturally distinct communities—can uncover contextual nuances often overlooked in mainstream prosthetics research.

CONFLICT OF INTEREST

The authors declare no conflict of interest related to the publication of this article.

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