Neuroplasticity and cortical remapping in users of advanced myoelectric prosthetics

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April 30, 2025

Abstract:

This literature review explores the neurobiological and technological mechanisms of neuroplasticity and cortical remapping in users of advanced myoelectric prosthetics. These two phenomena enable the brain to adapt structurally and functionally following limb loss and subsequent prosthetic integration. The review examines how neural pathways are reorganized, how users gain motor control over prosthetic limbs, and how AI-based technologies like
brain-computer interfaces (BCIs) and adaptive machine learning enhance this integration. Ethical and societal challenges, such as issues of identity, accessibility, and legal responsibility, are discussed. The review also highlights the importance of personalized rehabilitation
strategies and points out areas where further interdisciplinary research is needed.

Key words :
neuroplasticity, cortical remapping, myoelectric prosthetics, BCI, rehabilitation

Background Information :

The integration of advanced myoelectric prosthetics into the human body is a fascinating frontier in neuroscience and bioengineering. Central to this integration are two key processes: neuroplasticity, the brain's ability to form new connections, and cortical remapping, the reassignment of functions in the brain's cortex. These mechanisms allow users to regain control and sensation over prosthetic limbs, making the technology functionally effective and experientially meaningful. Understanding these neurological adaptations hasvast implications for medicine, robotics, and ethics in human augmentation.

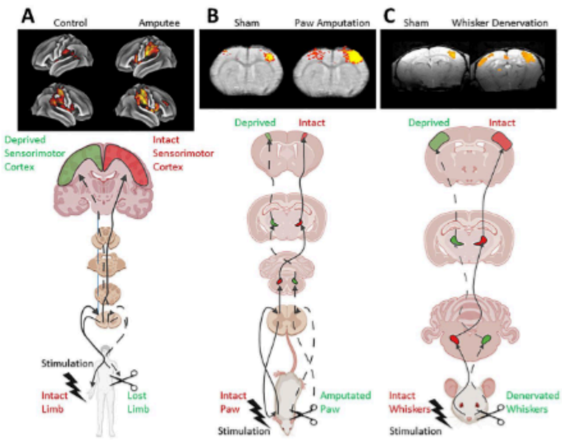

Figure 1. Cortical remapping in response to sensory deprivation from limb, paw, or whisker loss.

Purpose of the Review :

This review aims to answer the following questions:
How do neuroplasticity and cortical remapping facilitate the integration of advanced Myoelectric prosthetics?
What role does artificial intelligence play in this adaptation process?
What ethical and societal issues arise from the use of such advanced neuroprosthetics?
By investigating these themes, we aim to shed light on both the opportunities and challenges in optimizing brain-prosthesis interaction.

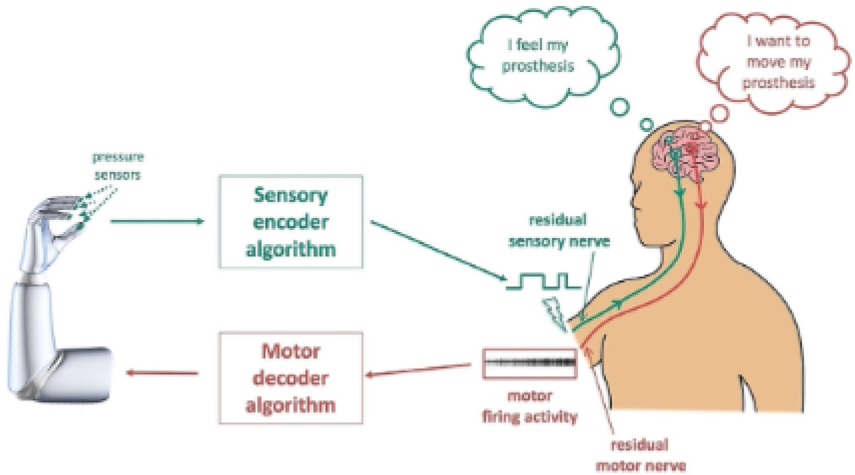

Figure 2. How Prosthetics Connect to Residual Nerves for Sensory Feedback and Movement

Previous Research and Findings :

Neuroscientific research has shown that neuroplasticity plays a vital role in adapting to limb loss and the use of prosthetics. The brain begins to reassign the areas previously devoted to the lost limb, a process known as cortical remapping. This leads to phenomena such as phantom limb sensations, where the user still feels the presence of the missing limb. Advanced prosthetics integrate with these neural processes by using BCIs to decode brain signals and machine learning to adapt device behavior over time. Feedback mechanisms, including haptic sensors, help retrain the user's brain to associate prosthetic movement with real-world action. Furthermore, VR training platforms enhance this learning by simulating controlled tasks that promote neural reorganization.
A 2017 study published in Frontiers in Neuroscience demonstrated that cortical excitability increased in the motor cortex contralateral to an ischemic nerve block, showing
How rapidly the brain can reorganize in response to artificial input.

Gaps in the Literature :

Despite significant progress, several gaps remain:
Long-term neural impacts of continuous brain-prosthesis interaction are not fully understood.
Variability among users in adaptation speed and effectiveness suggests a need for more personalized protocols.
Limited data exist on pediatric or elderly populations using these technologies.
Ethical questions around identity alteration and neural enhancement have been raised but not thoroughly examined through empirical studies.

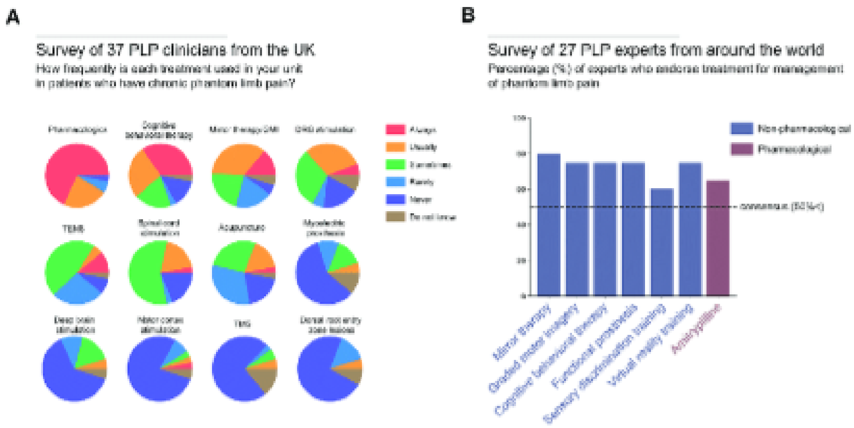

Figure 3. Global Treatment Trends for Chronic Phantom Limb Pain (PLP): Clinician Surveys from the UK (N=37) and International Experts (N=27) on Pharmacological vs. Non-Pharmacological Interventions

Conclusion :

Summary of Key Findings :
Neuroplasticity and cortical remapping are essential for adapting to advanced myoelectric prosthetics. These processes are enhanced by AI technologies such as BCIs, machine learning learning algorithms, and sensor-based feedback systems. They allow users to regain control and experience intuitive interaction with their artificial limbs.

Implications :
These findings emphasize the need for multidisciplinary collaboration across neuroscience, engineering, ethics, and rehabilitation. Better understanding of neural mechanisms can lead to smarter prosthetic design and more effective rehabilitation strategies.

Suggestions for Future Research :

Future studies should:
Investigate longitudinal outcomes of brain-prosthetic integration.
Explore AI-driven personalization in rehabilitation platforms.
Address ethical frameworks for neural enhancement and data privacy.

Application:

The integration of AI in neurorehabilitation has real-world potential to transform prosthetics, making them more responsive, affordable, and accessible. These advances could revolutionize how people with limb loss regain autonomy and reintegrate into society.