

PROCEEDINGS

Recent Advances in AI-Enabled Brain–Computer Interfaces for Motor Rehabilitation

Kaixin Xu¹, Qinglei Li¹, Jie Wu¹, Xiaohui Chen¹, Yao Wei¹, Xing Gao², and Jaeyoung Park^{1,*}

¹College of Art and Physical Education, Kyungil University, 50, Gamasil-gil, Hayang-eup, Gyeongsan-si, Gyeongbuk-do, Korea

²School of Kinesiology and Health, Graduate School, Harbin Sport University, Harbin, 150008, China

*Corresponding Author: Jaeyoung Park. Email: sports@kiu.kr

ABSTRACT

Motor dysfunction is a major disabling consequence of neurological disorders such as stroke, spinal cord injury, and cerebral palsy, fundamentally arising from impaired neural pathways between motor intention generation and limb execution. Brain–computer interfaces (BCIs) establish direct communication between the brain and external effectors, enabling the direct mapping of neural activity to functional output. Although advances in flexible neural interfaces, low-damage implantation techniques, and artificial intelligence–based decoding have driven the transition from short-term discrete control to long-term continuous modulation, interface instability–induced signal degradation and decoding errors are further amplified by neural signal non-stationarity and inter-individual variability, thereby forming an interface–signal–decoding coupling bottleneck that limits long-term stable operation and clinical application. This review systematically summarizes recent progress in BCIs for motor rehabilitation, analyzes the design of different neural interfaces and their stability mechanisms, and compares the applicability of mainstream decoding methods for non-stationary signal processing. In addition, the application potential of BCIs in exoskeletons, neuroprostheses, and rehabilitation robots for stroke recovery is discussed. Finally, we highlight that the integration of neural interface engineering and adaptive intelligent decoding will be critical for achieving long-term stability, individual adaptation, and clinically sustainable application of BCI systems.

KEYWORDS

Brain–computer interface; motor rehabilitation; neural interface stability; neuroprosthetics; intelligent decoding

Acknowledgement: We would like to express our sincere gratitude to the individuals and organizations who have made valuable contributions to this work. Special thanks go to Professor Changhong LINGHU for his meticulous guidance on this paper. His professional advice and rigorous attitude have significantly enhanced the quality and academic value of the article.

Funding Statement: This research was funded by the Natural Science Foundation of Heilongjiang Province of China (YQ2025A001).

Conflicts of Interest: The authors declare no conflicts of interest to report regarding the present study.



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