

Human-Machine Interaction for Rehabilitation Robots: Benefits and Detriments

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Abstract

Rehabilitation robots have emerged as a transformative tool for patients recovering motor and cognitive functions after nervous system injuries, yet their clinical success hinges critically on the quality of human-machine interaction (HMI) during therapy. On the benefit side, interactive robotic systems enable repetitive, high-intensity, and quantitatively measurable training that traditional therapy cannot easily match; multimodal sensing and closed-loop control allow real-time adaptation to each patient's motor state, promoting neuroplasticity and improving recovery outcomes. Brain-computer interface (BCI)-driven interaction further engages patients' active participation, turning passive exercise into goal-directed, brain-informed training. On the detriment side, however, HMI in rehabilitation robotics faces substantial and often underappreciated challenges: safety risks from force misestimation or delayed response, patient discomfort and fatigue imposed by rigid interfaces, over-reliance on robotic guidance that may weaken residual motor pathways, and the fundamental difficulty of decoding human intention reliably and transparently. Existing interactive control strategies still struggle to balance assistance and resistance, adapt across heterogeneous patient populations, and maintain trust and acceptance in real clinical settings. In this talk, we present recent exploratory studies on multimodal biological signal processing, BCI-enabled human-robot interaction mechanisms, and closed-loop motion control for rehabilitation robots, with a particular focus on how these technologies amplify therapeutic benefits while mitigating interaction-related detriments. We conclude by discussing future directions toward safer, more adaptive, and patient-centered human-machine collaborative rehabilitation.



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