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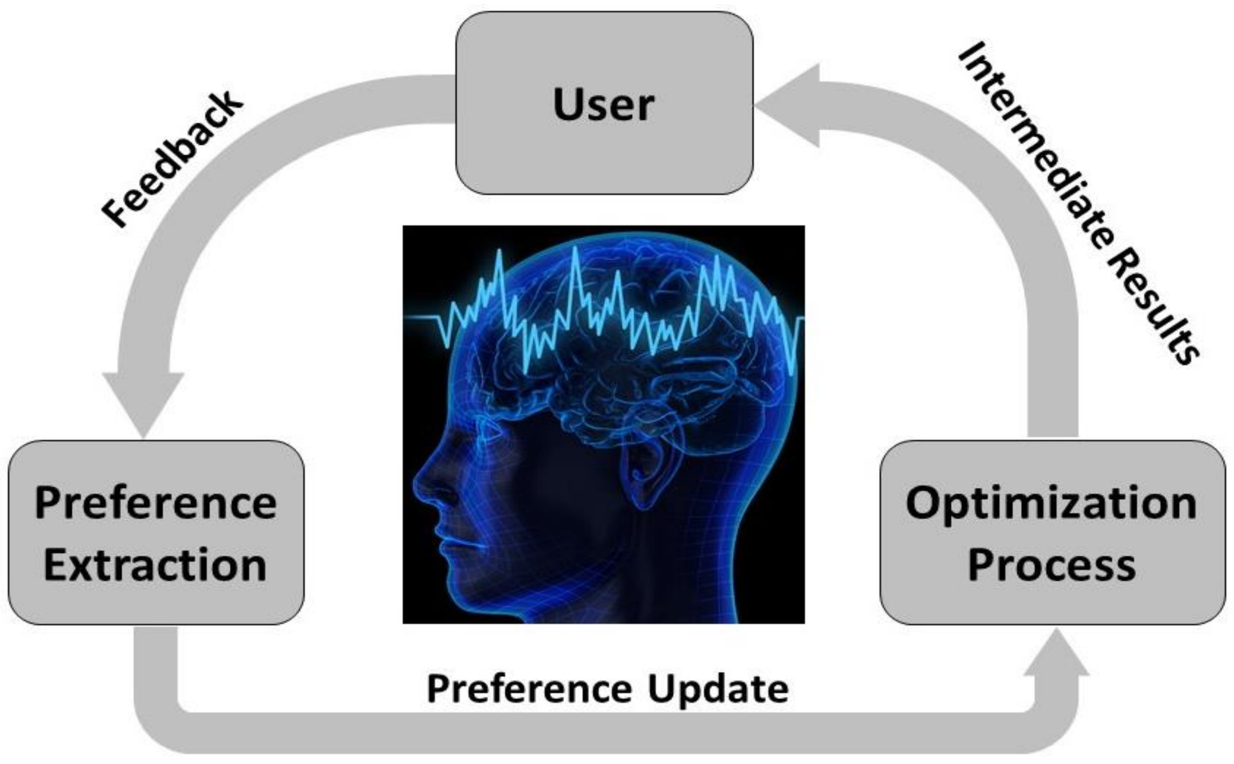
Brain-Computer Interface in Assistive Wearable Robots

Goal: Reaching a "common language" between the assistive system and the user, allowing the assistive system to quickly adapt its behavior to better match the user's intention and action. The aim is to investigate the feasibility of implementing the concept of passive Brain-Computer Interface (pBCI) [1] in the field of assistive wearable robotics.

Methodology: Brain-in-the-loop Optimization (**BILO**); Introducing a framework of measuring brain signals to approximate human evaluation of gait assistance. Hence, achieving a human-machine system in which the machine is learning from the human and adapting its behavior to the desired state of the user.

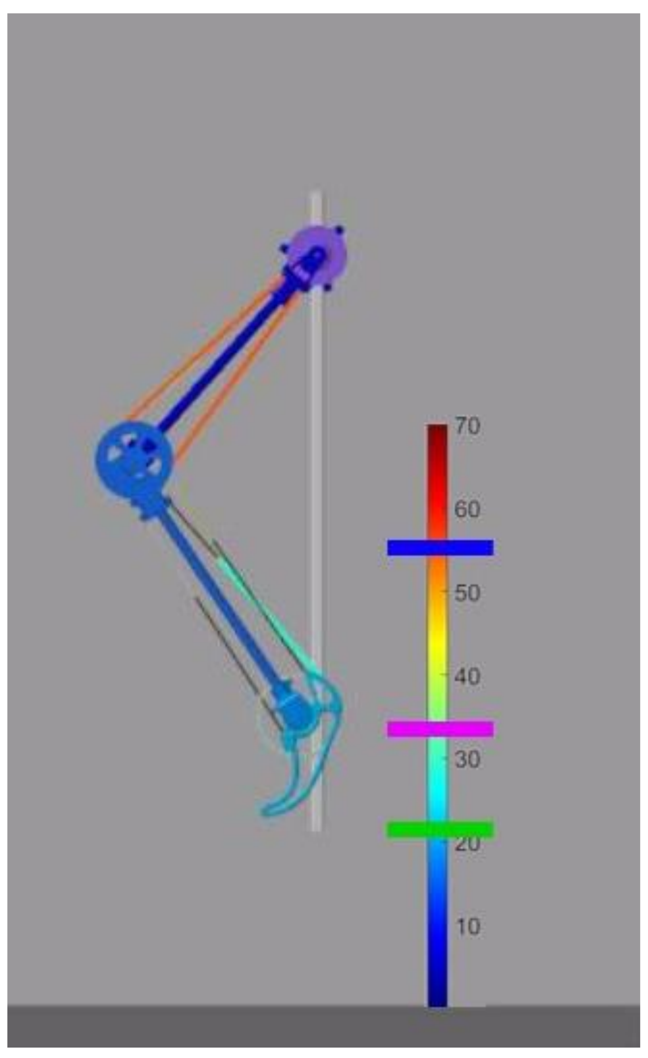


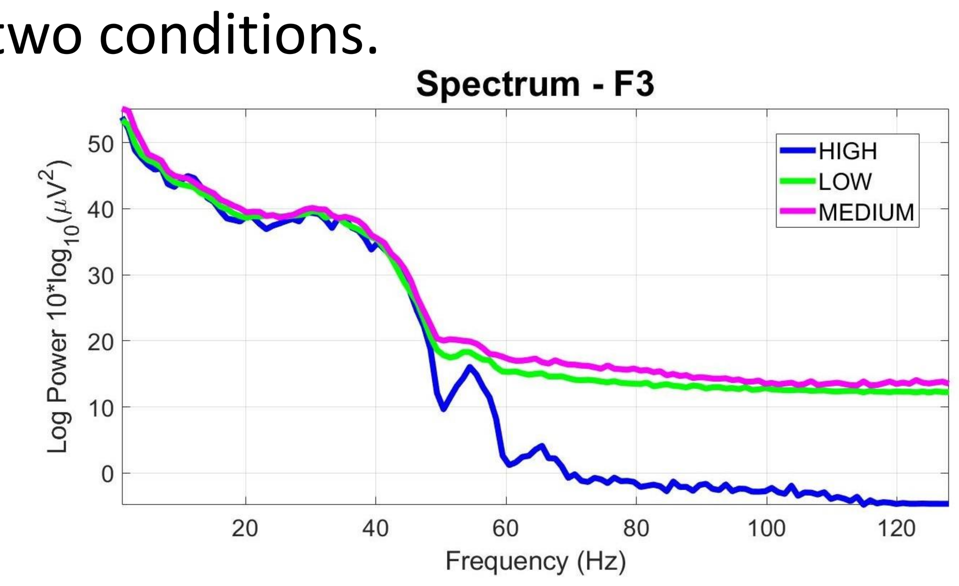
Challenges

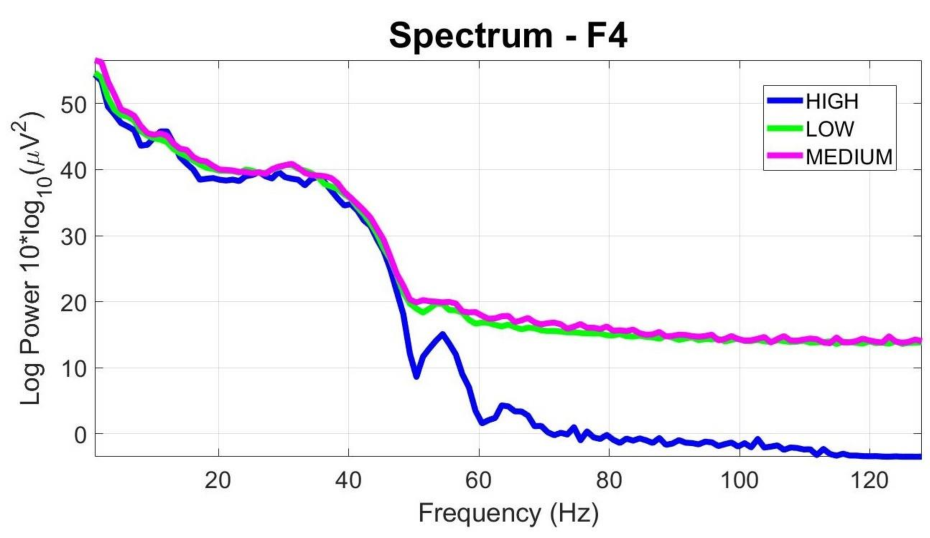
- The communication bottleneck in physical human-machine interaction results in a coordination mismatch.
- Valid biomechanical and neurophysiological models of human are lacking.
- Human-in-the-loop optimization methods are time-consuming since they require collecting extensive data sets for individual subjects.
- Human movement cost function is unknown and might change in different situations.

Experiment 1

- The aim of this proof-of-concept study was to investigate whether human perception of robot's movement was interpretable from the brain signals.
- Participants were seated in front of a screen and watched a video of a hopping robot with different hopping heights while their EEG signal was measured.
- Three different hopping heights were shown to the participants (High, Low, and Medium)
- A change in the power spectrum of EEG signals from two channels (F3 and F4) was observed in higher frequencies for different hopping conditions. This feature shows a clear indication for the best condition (highest hopping height) compared to the other two conditions.

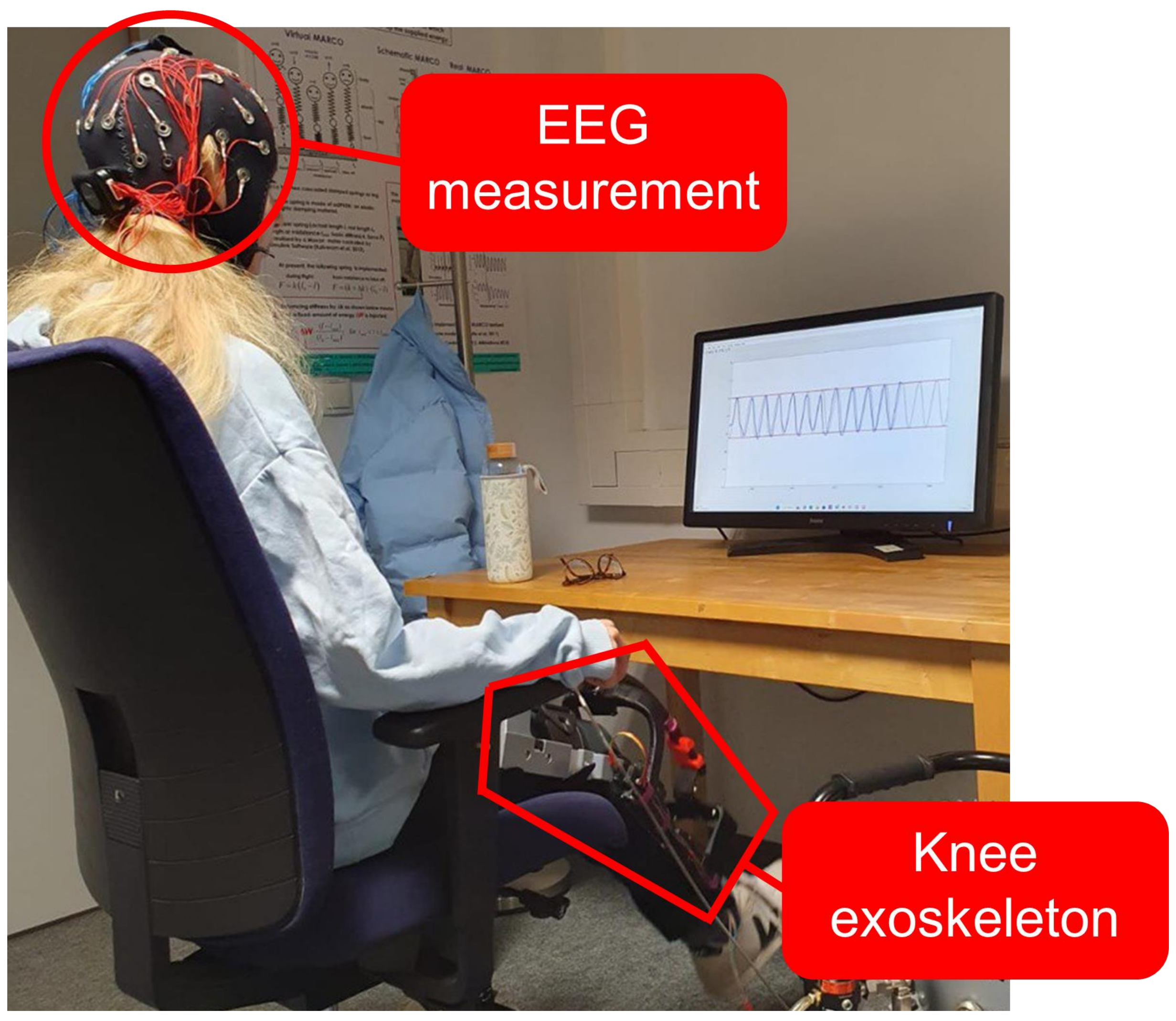






Experiment 2

- The goal of this experiment is to interpret user preference from their brain signals
- Participants are asked to swing their knee while sitting down and wearing a single degree of freedom knee exoskeleton
- In each trial, the device's parameter was changed and participants gave a preference score after moving for 30 seconds.
- The EEG signal was measured with the aim of finding a correlation between the brain response and the preference score.



Outlook

- The aim of the proposed implicit control is to get assistance from the human brain's reaction (to changes) to adapt the exo to the user's desires without requesting the user to contribute to control; hence, achieving a passive Brain-Computer Interface.
- The human brain assists the exo to learn how to optimize movement assistance.
- This mutual assistance paradigm within the BILO framework could provide a breakthrough not only in gait assistance but also in any human-robot interaction application.

[1] Zander, Thorsten O., et al. "Neuroadaptive technology enables implicit cursor control based on medial prefrontal cortex activity." *Proceedings of the National Academy of Sciences* 113.52 (2016): 14898-14903.