ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Brain-Robot Interaction: Inferring Subjective Neuroprosthesis Behaviour from Human EEG

A. Billard

I. Batzianoulis

S. Wei

A. Saurav

J.d.R. Millán

F. Iwane

R. Chavarriaga

Hasler Stiftung, Cyber Human Systems Workshop, Bern – October 2019

Residual Motor Capabilities May not Suffice to Control Robots

Small accuracy in wrist rotation and grasping

↓

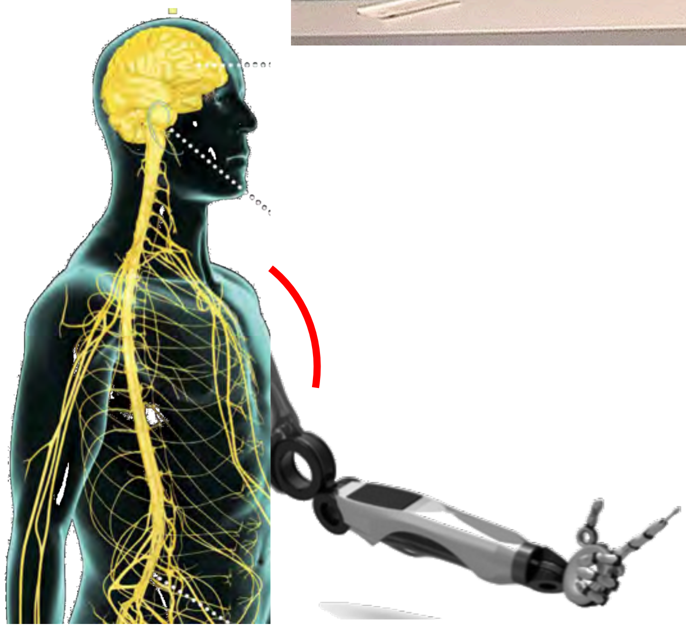
Compensation with moving the torso

↓

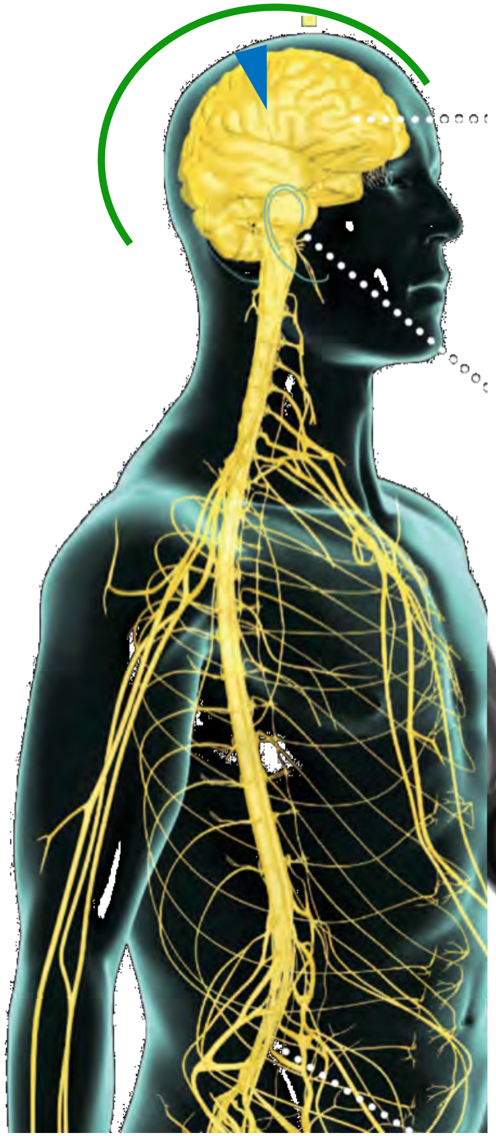
Mechanical motion and discomfort

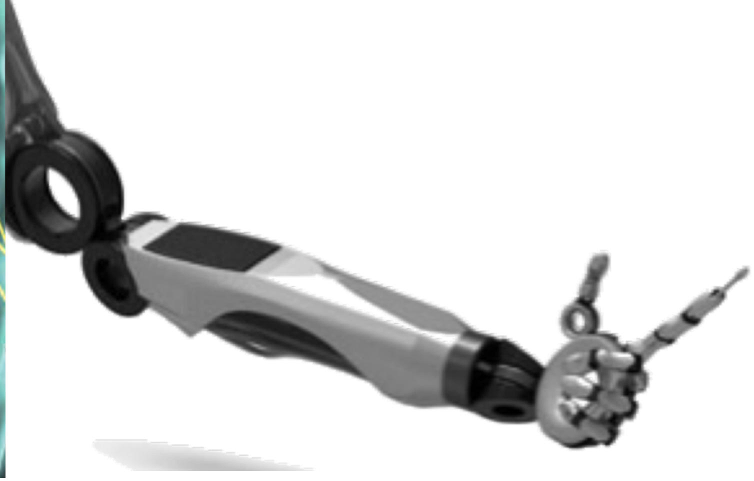
↓

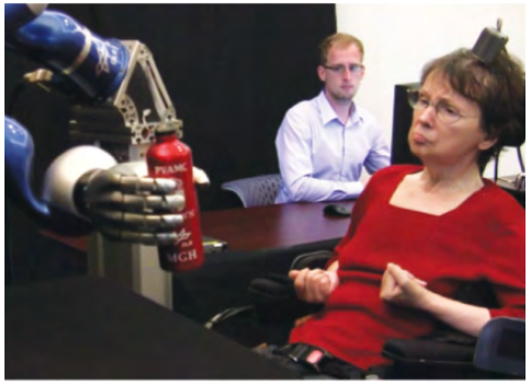
Rejection of the device



Current BMIs not Suitable for Long-Term Use







Implanted electrodes
Hochberg *et al.*, 2012

Need for recalibration
Long training
Not dexterous control

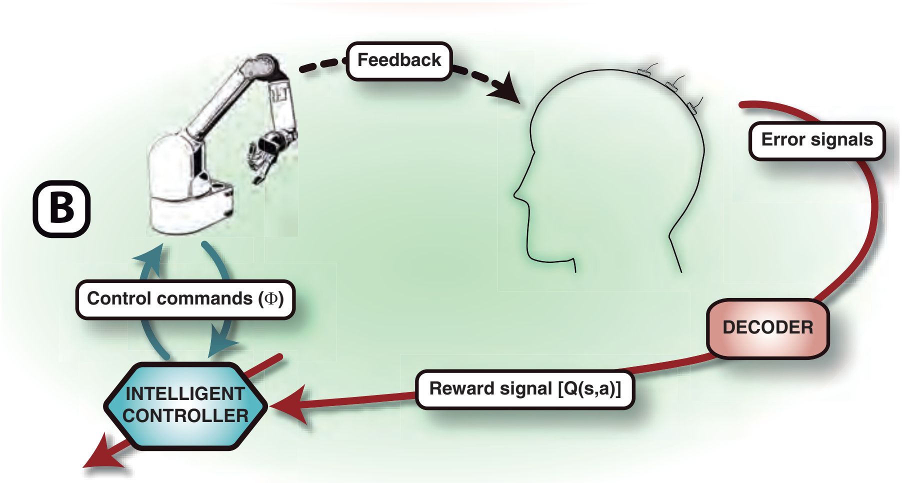
Non-Invasive BMIs
Leeb *et al.* 2010

Hybrid brain-machine interfaces for natural neuroprosthetic control

Reliable, precise control of neuroprostheses for long periods of time without recalibration

Naturalness of prosthetic control

Endow prosthesis with learning capabilities
Inverse Reinforcement Learning +
Error-related Brain Potentials



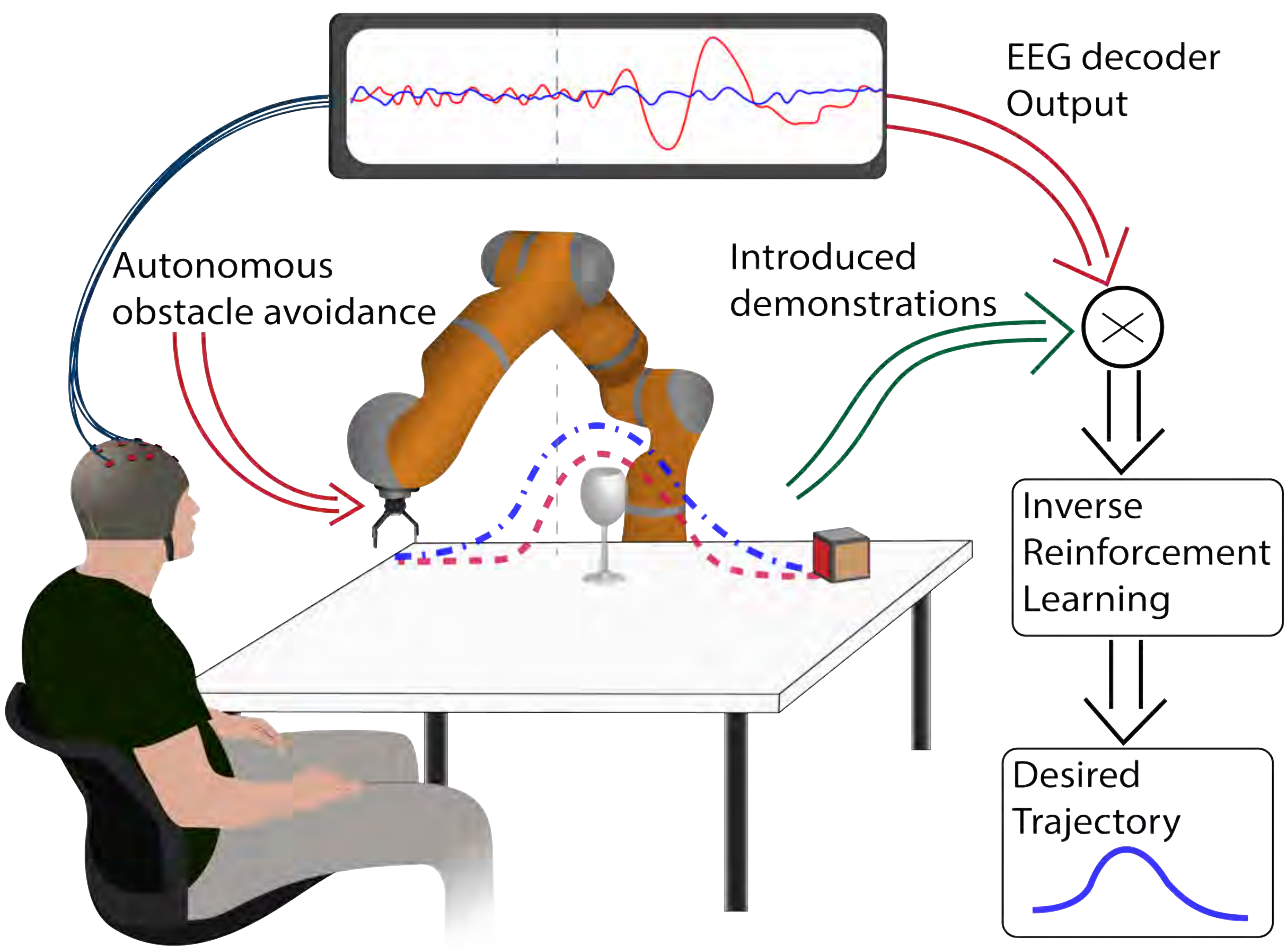
Inverse Reinforcement Learning (IRL)

Exploit demonstrations from experts to infer:

1. Optimal control policy
2. Reward function

Who are our experts? The (disabled) users themselves!

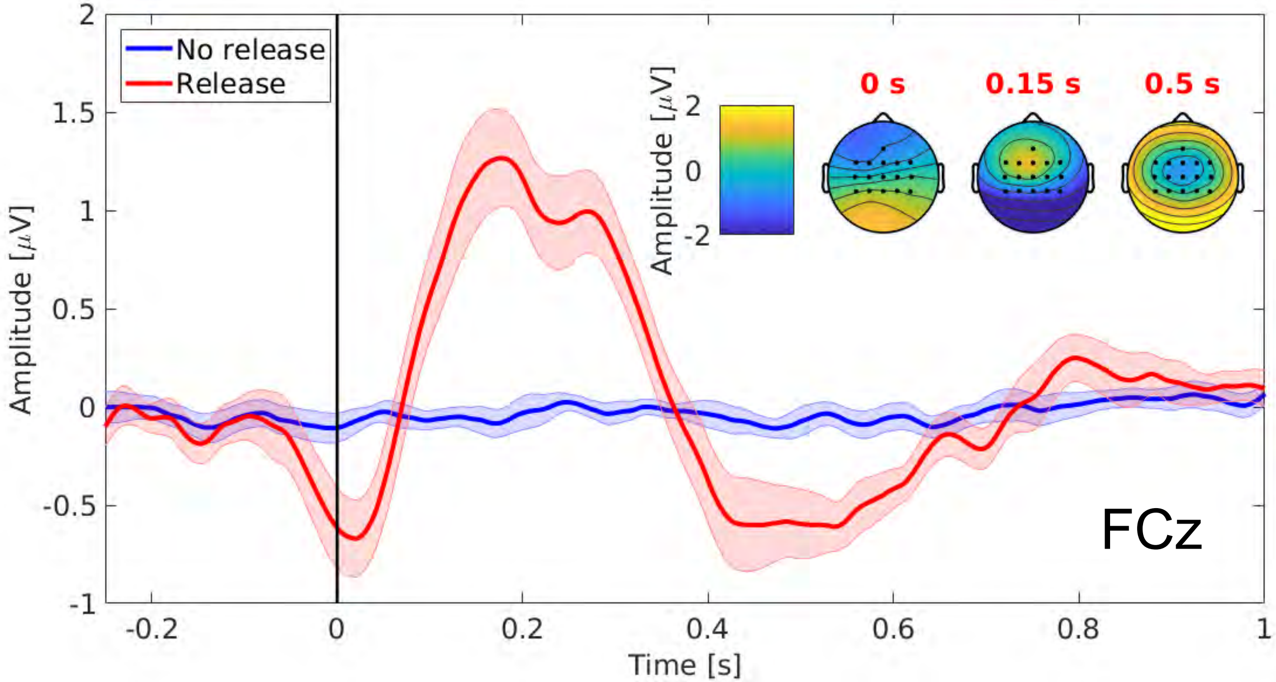
Inverse Reinforcement Learning



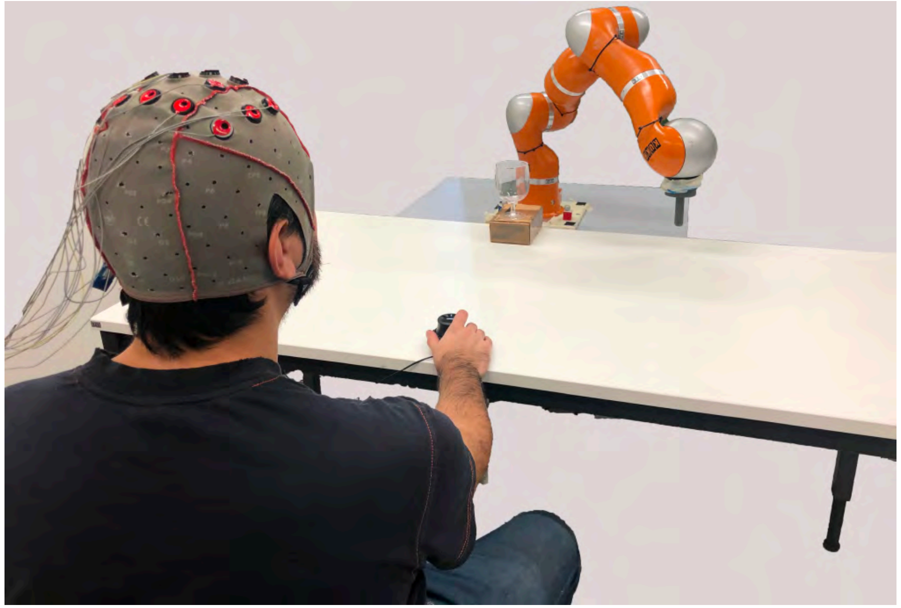
Error-related Brain Potentials (ErrP)

Main Challenge:

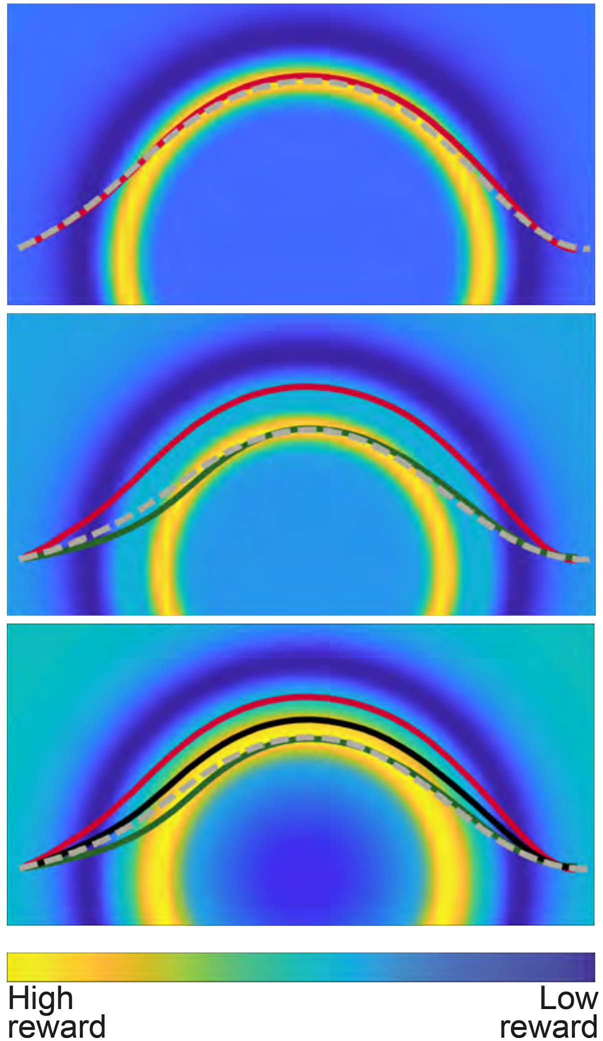
Detection of ErrP during continuous motion



IRL + ErrP: Experimental Set-Up & Results (I)



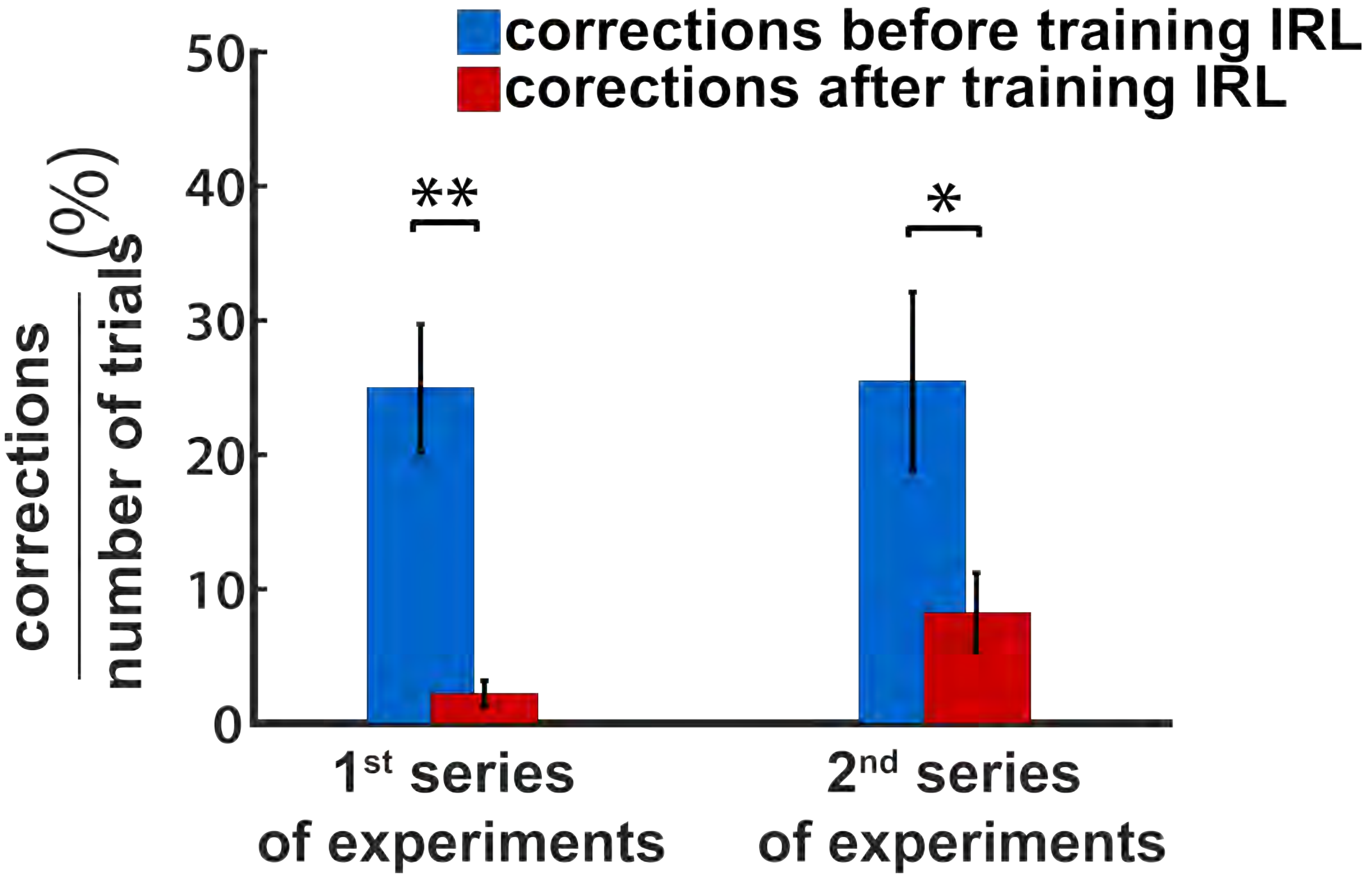
Evolution of the reward function when increasing the number of demos



Grey dashed lines: trajectory generated by IRL

Red, green and black lines: successive testing trajectories

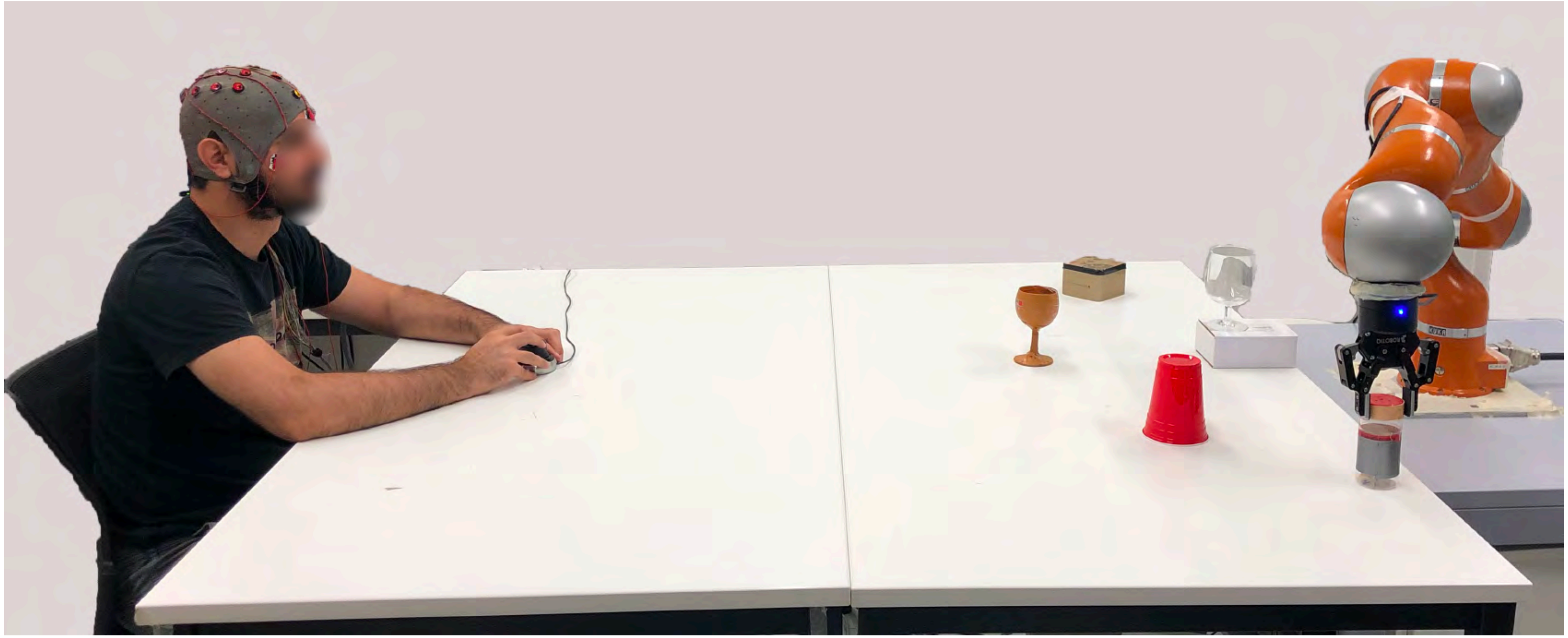
IRL + ErrP: Results (II)



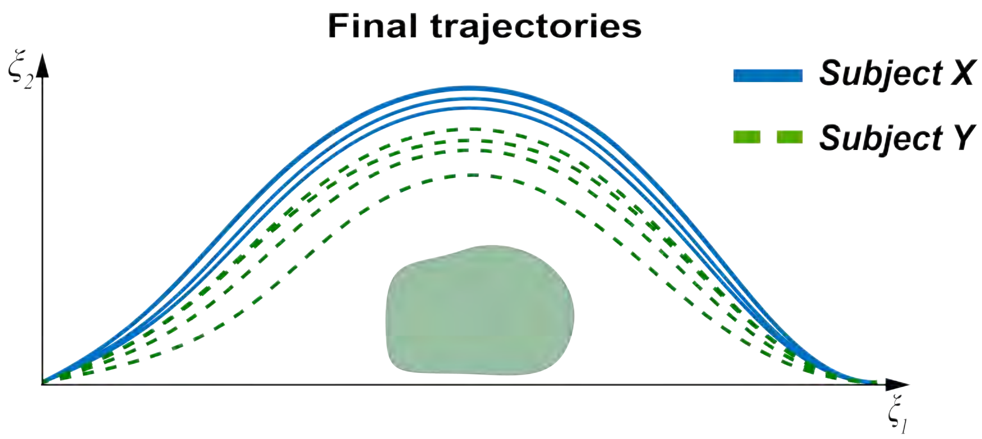
N=8 N=5

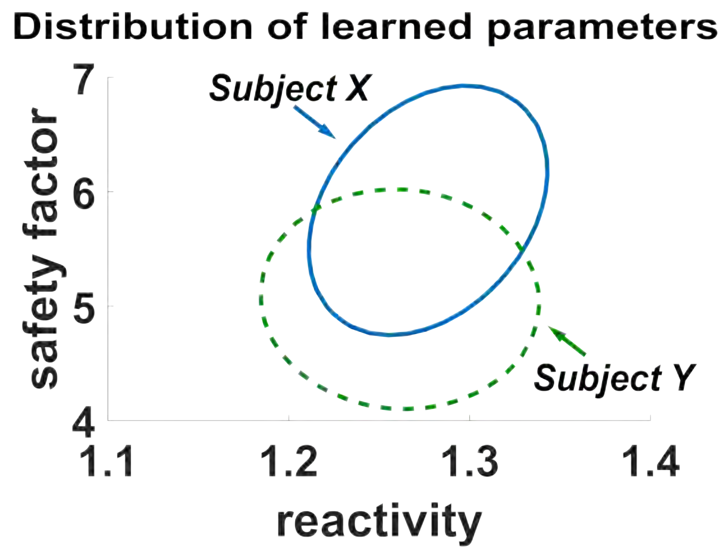
IRL + ErrP: Pick-and-Place Task

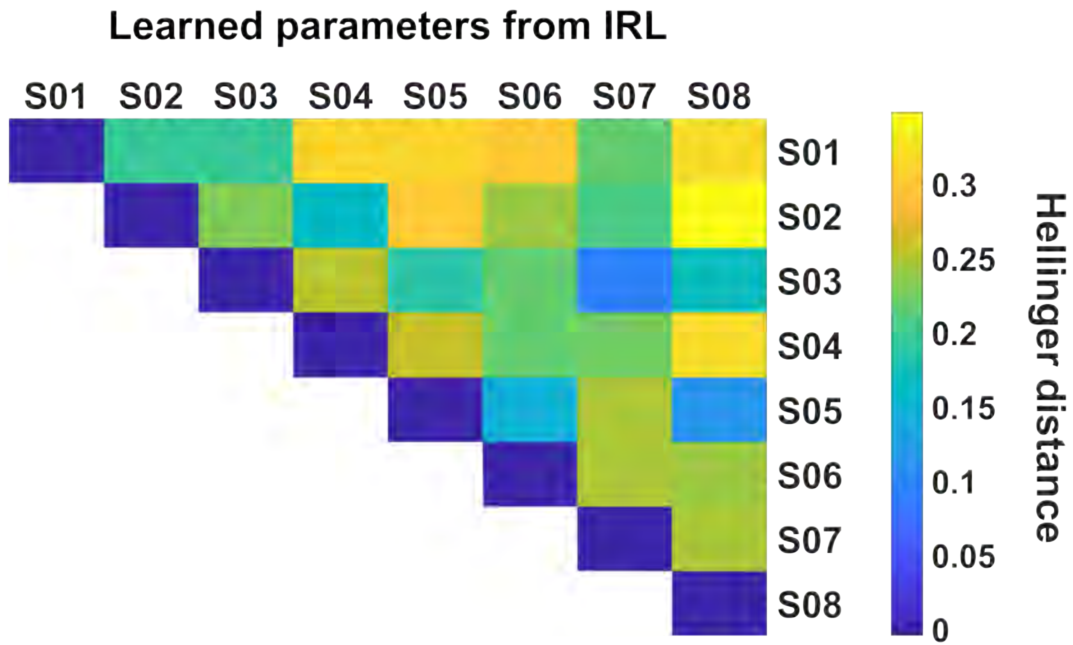
Training phase: same task as in Experiment 1



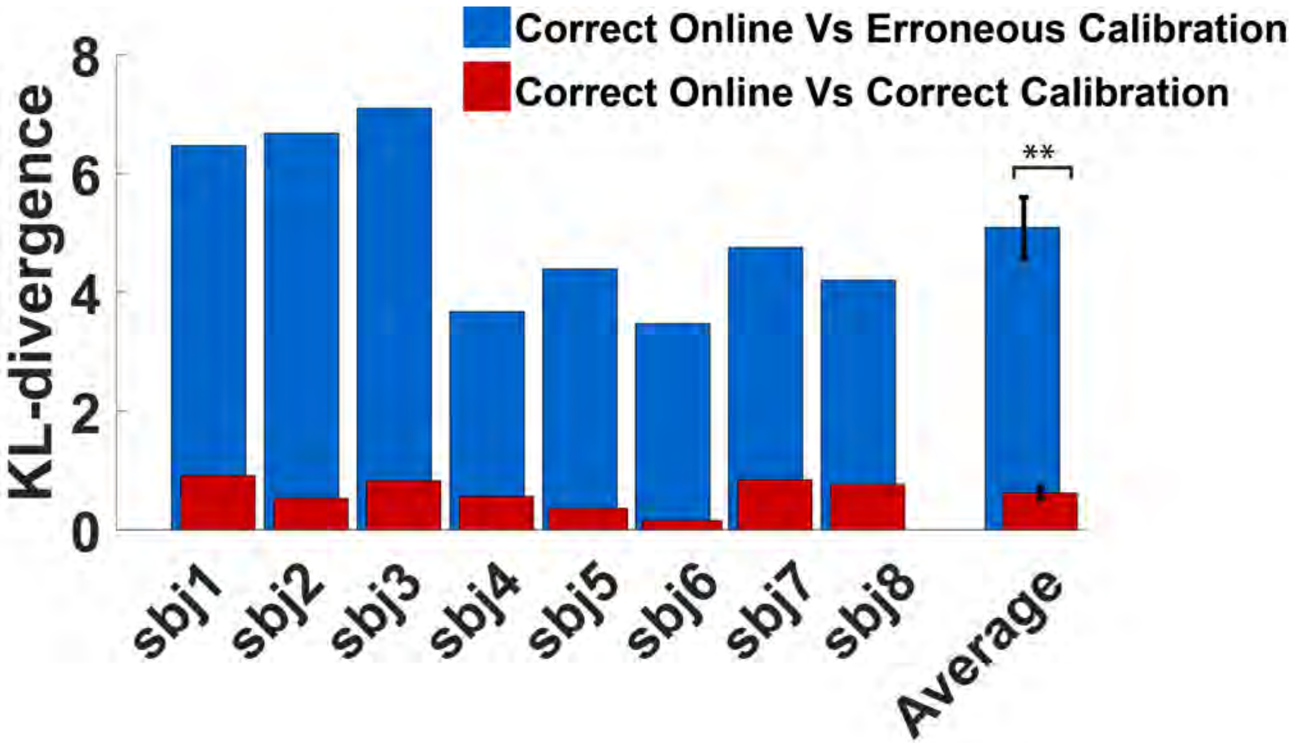
IRL + ErrP: Customization to Individual Preferred Trajectories (I)





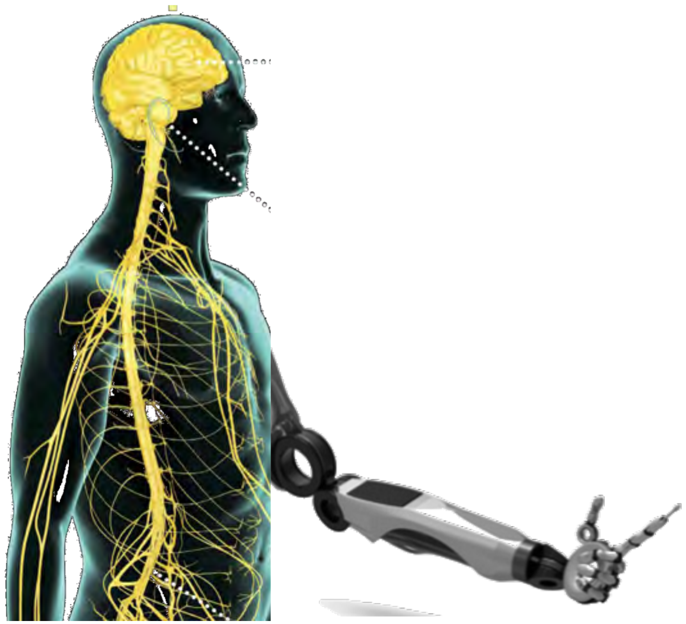


IRL + ErrP: Customization to Individual Preferred Trajectories (II)



Summary

Reliable, precise and natural control of neuroprostheses over long periods of time without recalibration



Overarching goal

System will continuously improve its performance, based on user's feedback

Neuroprothesis learns how to operate based on the individual user's own preferences

Pave the way to neuroprosthetic systems suitable for long-term, independent use

Outlook

1. Fast and robust intention detection
   Robust fusion of multimodal channels (**EEG**, **EMG**, **Eye-tracking**) according to their temporal characteristics and reliability

2. Validation with subjects with motor disabilities