cnbi
Defitech Foundation Chair in
Non-invasive Brain-machine Interface

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Brain-Computer Interfacing

José del R. Millán

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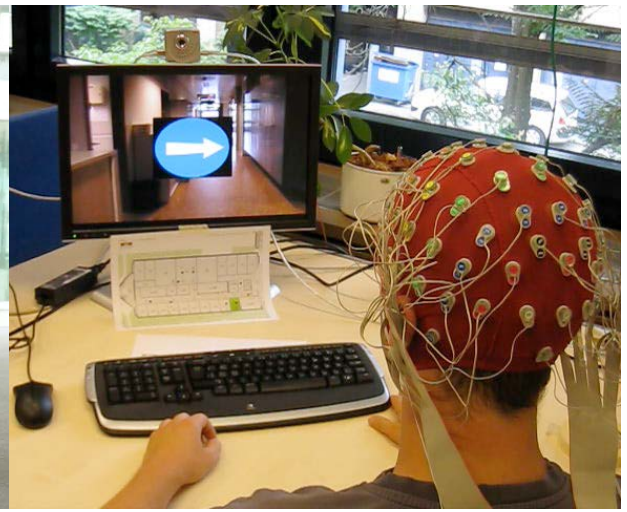
Center for Neuroprosthetics

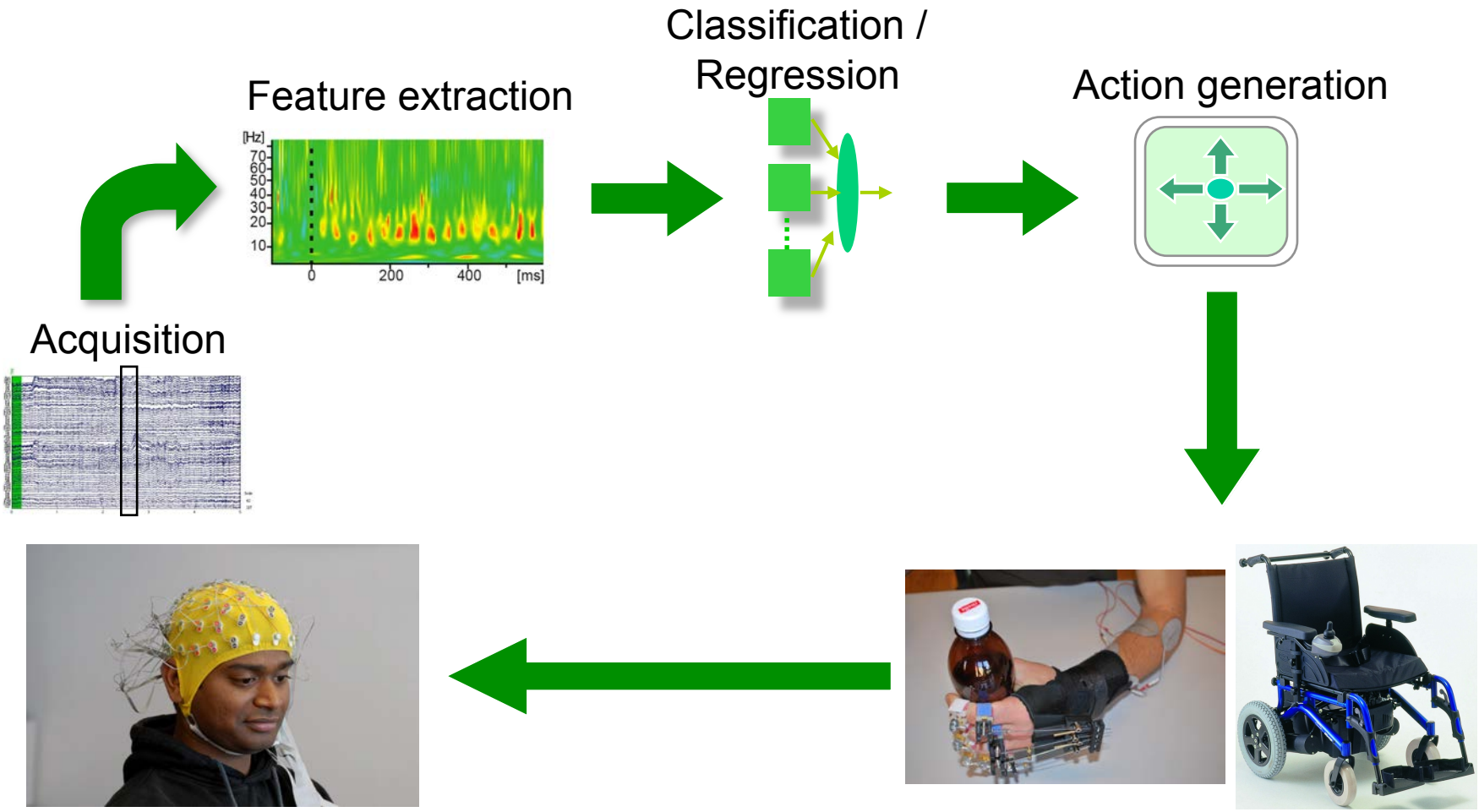
Ecole Polytechnique Fédérale de Lausanne





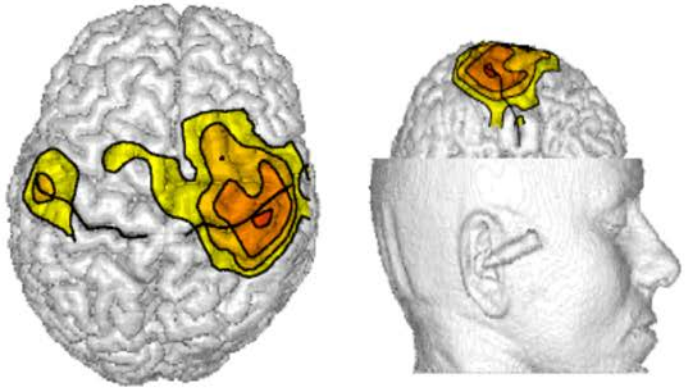
Brain-controlled Wheelchair

BMI Architecture

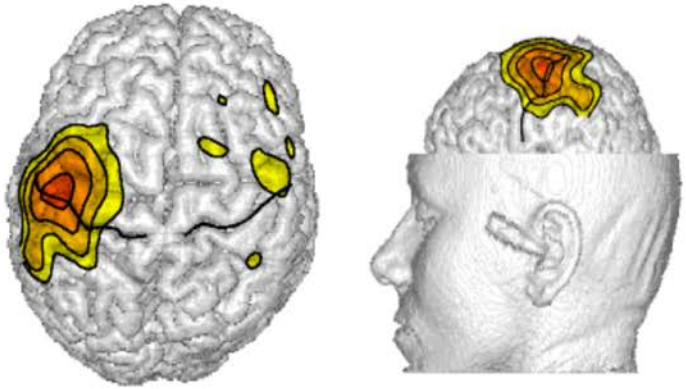


Augmentation: voluntary learning new skills

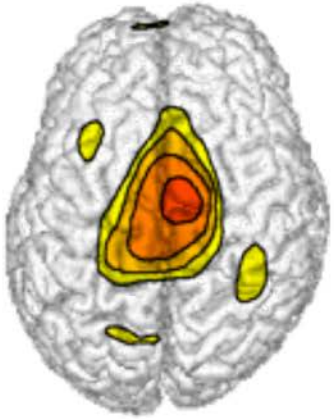
EEG Prototypical Patterns



Left hand 9-13 Hz



Right hand 9-13 Hz

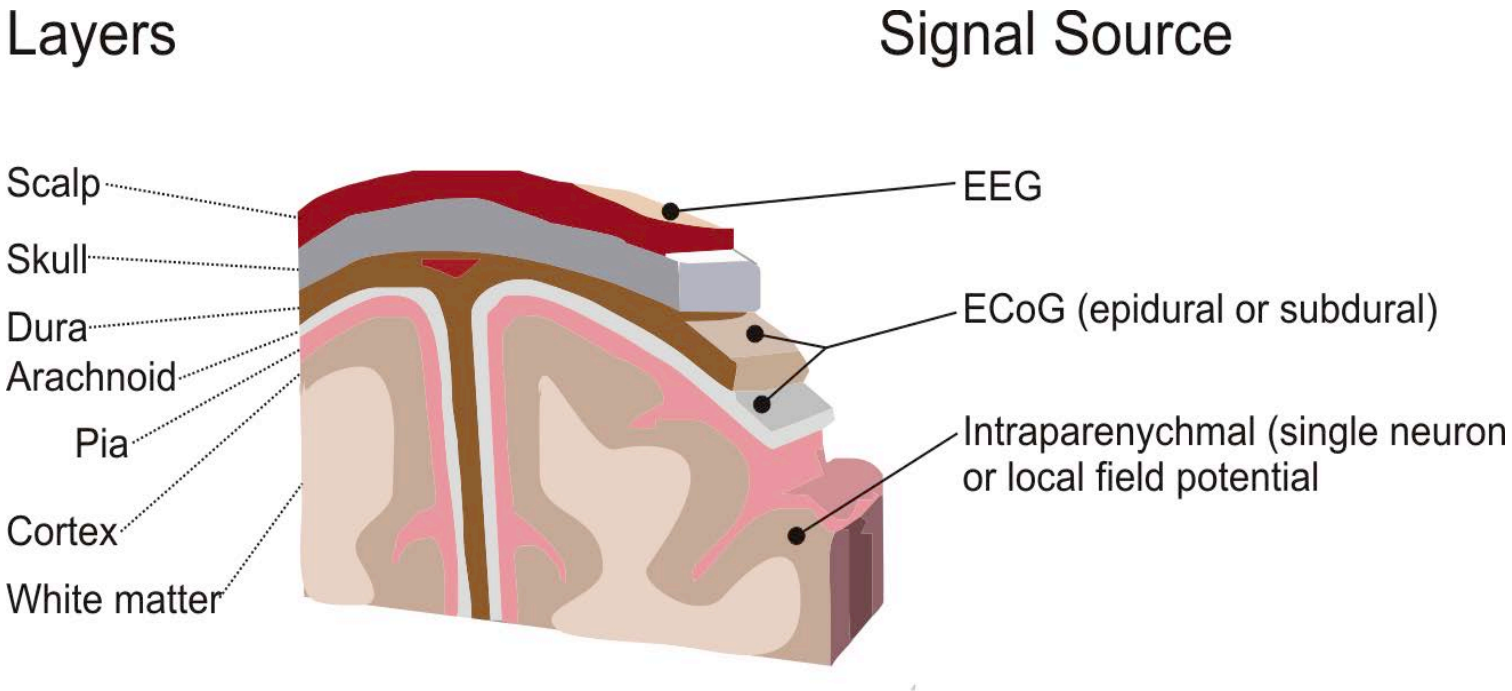


Foot motor imagery

18-23 Hz

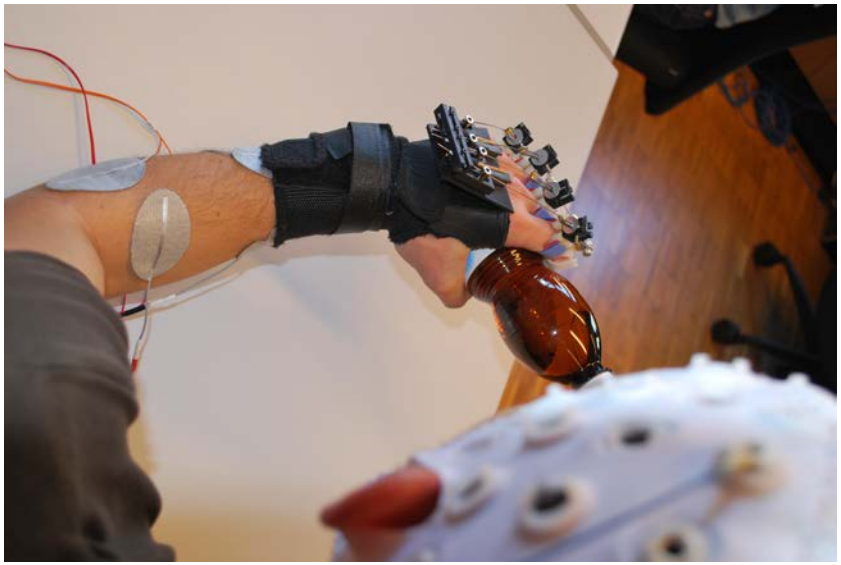
Courtesy: TU Graz

BMI Modalities: Electrical Activity



(Leuthardt et al., Neurosurg Focus 2009)

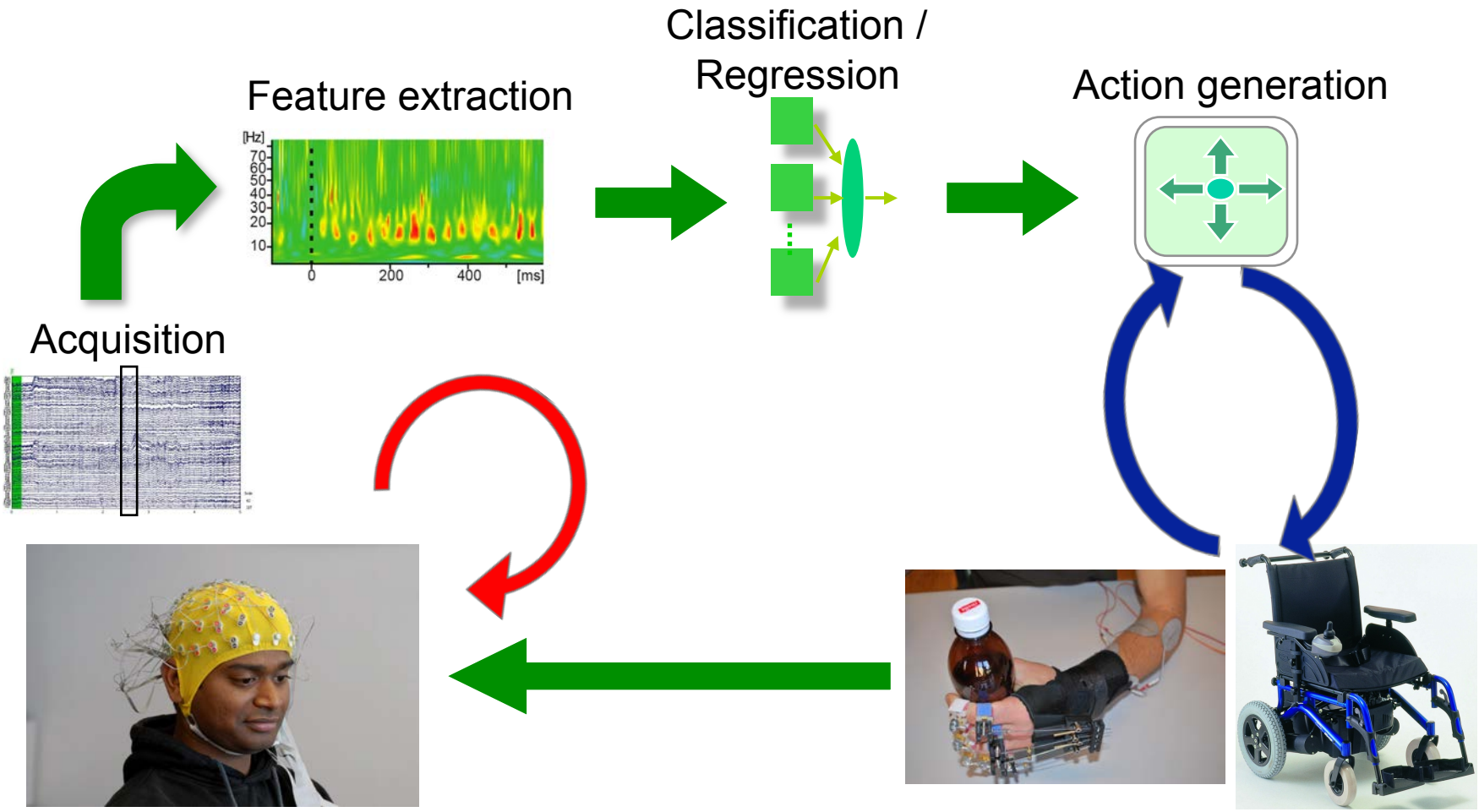
Brain-controlled Robots



➔ big challenge,
fast & **timing decision-making** is critical

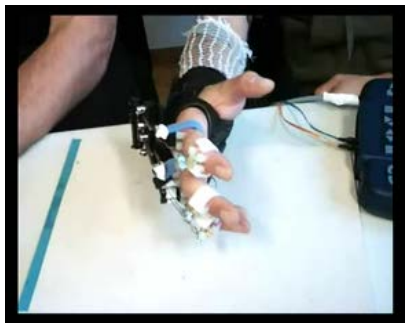
➔ How to bridge the **cognitive gap?**

BMI Architecture



Interaction Principles

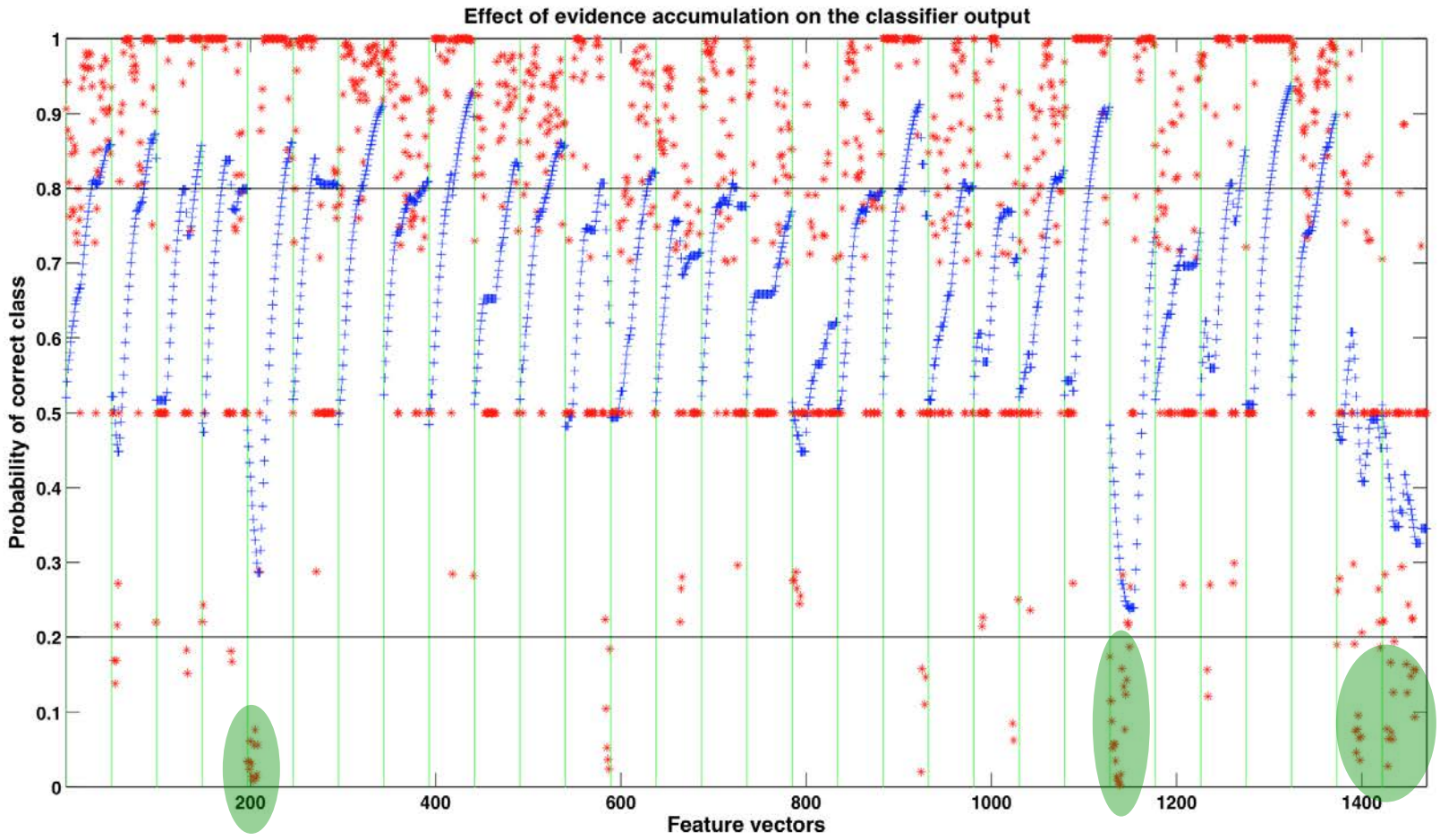
- **Asynchronous approach**
  - User can send commands anytime
  - Spontaneous activity, no external cues
- **Machine Learning Way to BMI**
  - Mutual learning process
  - Feature extraction & classification
- **Blending of Intelligences**
  - User's mental capabilities + intelligent device
  - Shared Control, Context Aware
- **Cognitive Interfaces**
  - Recognition of human mental states (e.g., error awareness, anticipation)



Handling Uncertainty

Serafeim Perdikis, Hamidreza Bayati, Ricardo Chavarriaga. *EPFL*

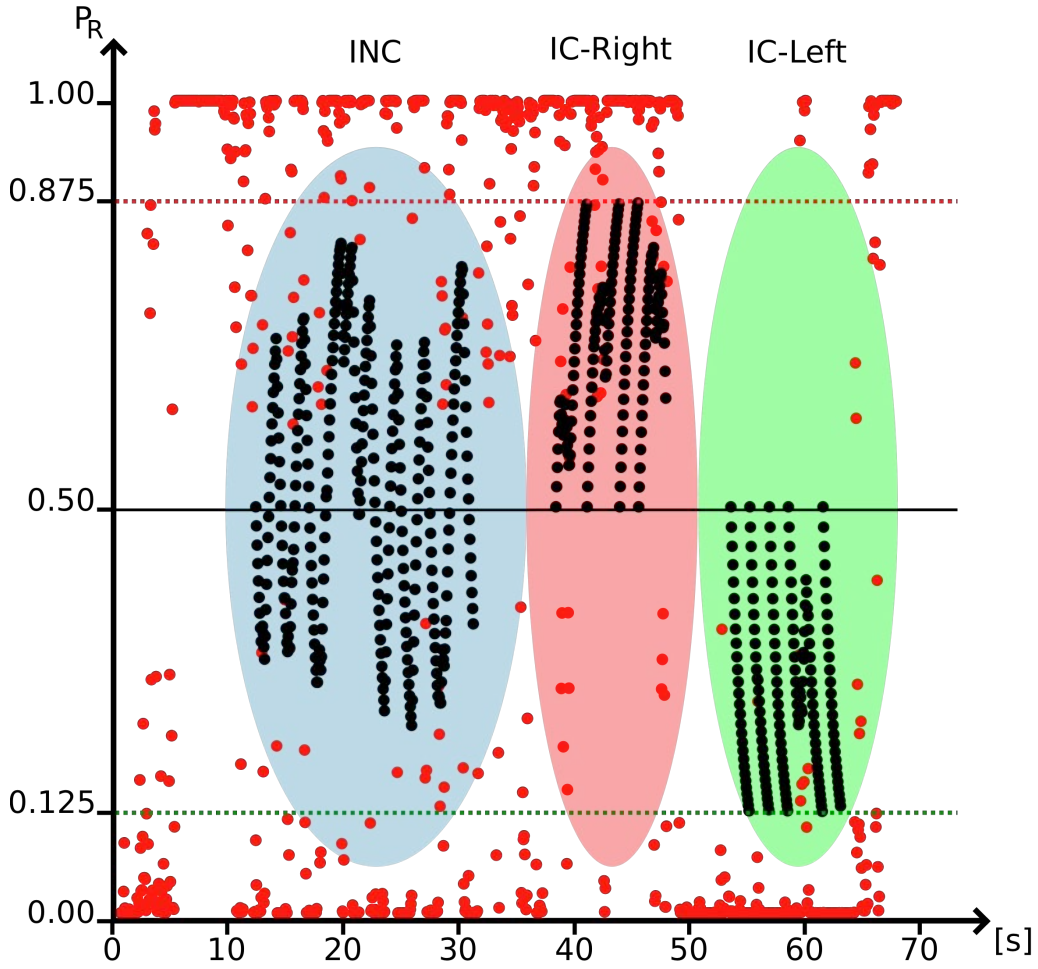
- Evidence Accumulation: Probabilistic Decision Making



Multitasking

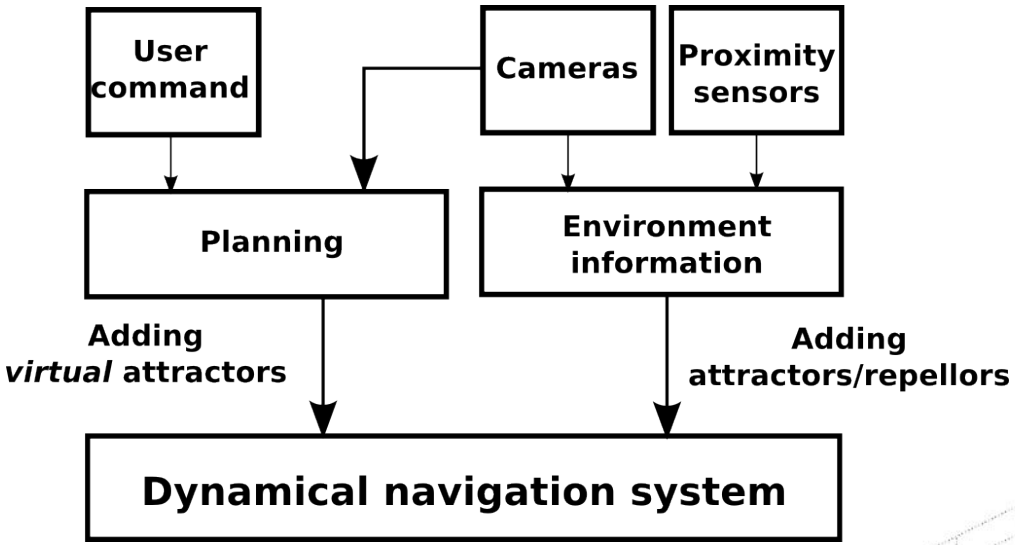
Michele Tavella, Serafeim Perdikis. *EPFL*

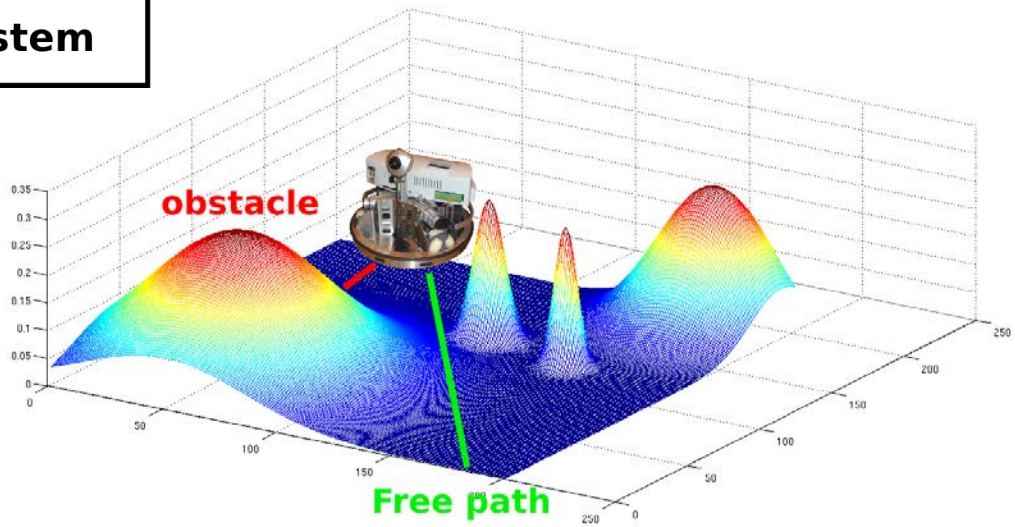
- ***Intentional non-control***



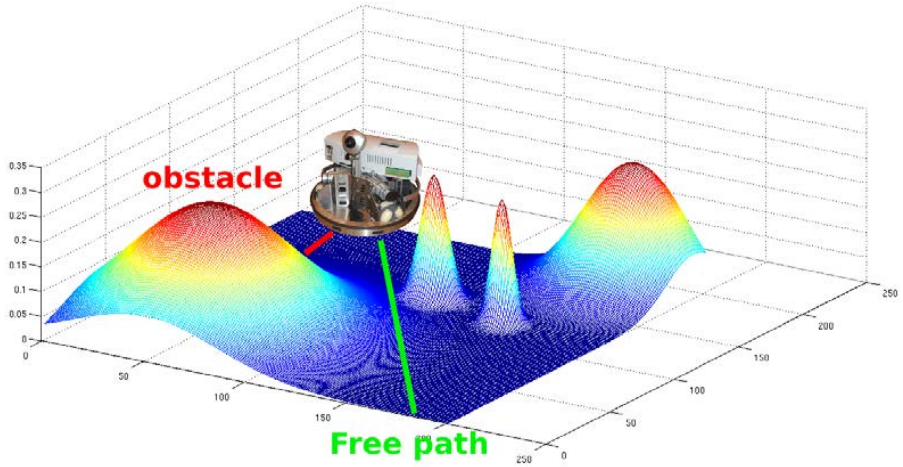
Multitasking & Intentional Non-Control

Adaptive Shared Control





Adaptive Shared Control

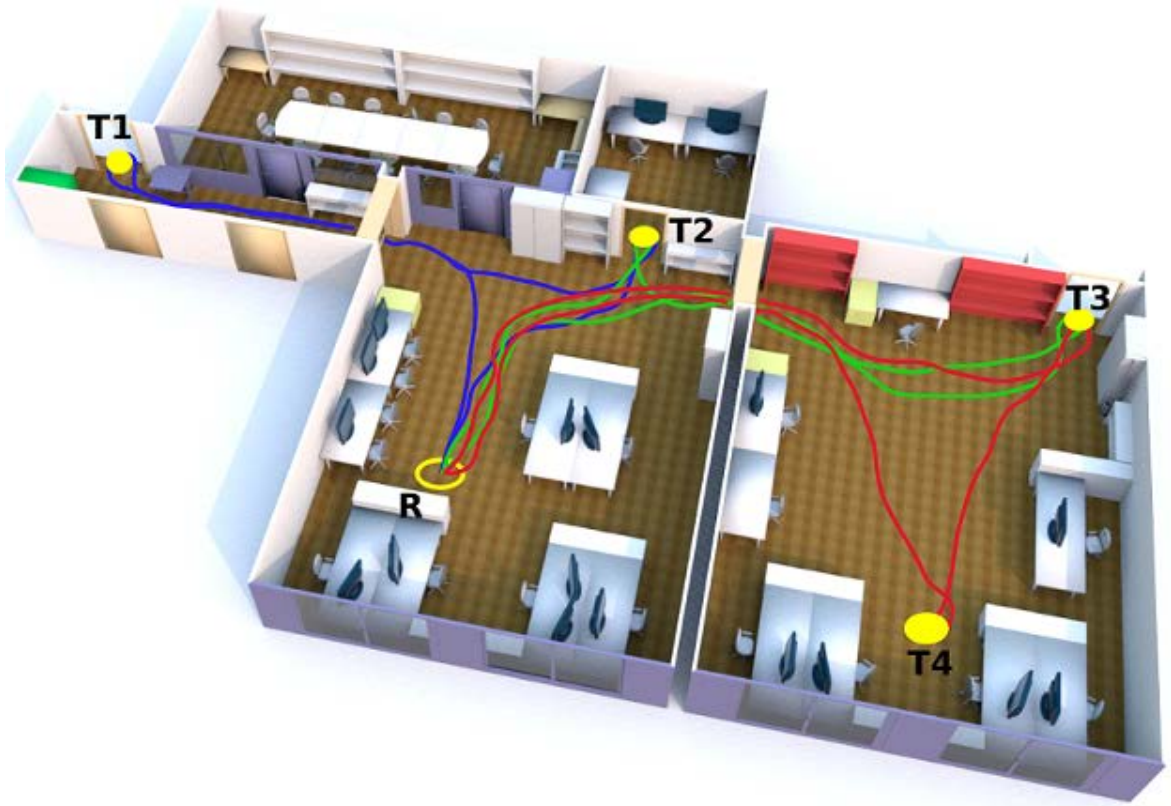


Telepresence Robot

Luca Tonin, Tom Carlson, Guillaume Monnard

- Target Population
  - Severely disabled people constrained to remain in bed

Telepresence Robot

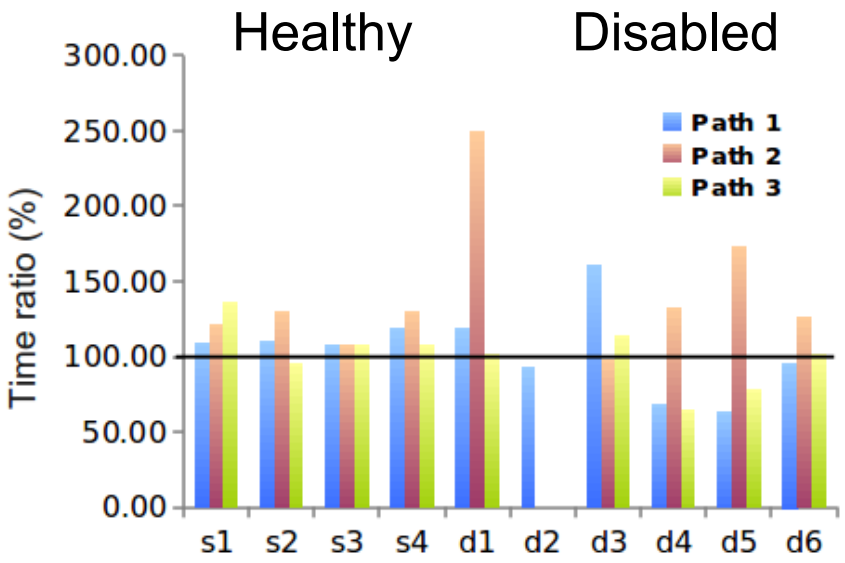


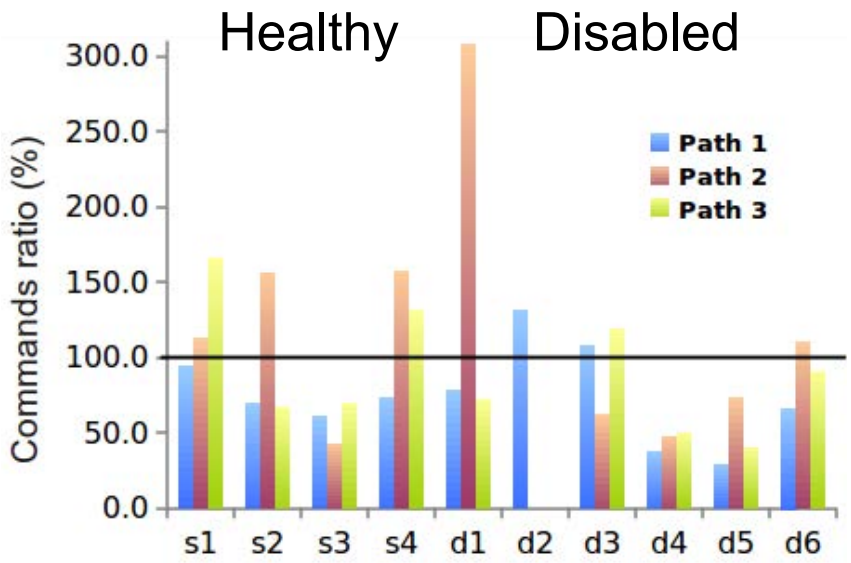
Manual control, mean:

	Path 1	Path 2	Path 3
Time [s]	285.6	253.8	298.9
Commands	29.3	27.5	27.0
Distance [m]	35.7	34.4	39.6

Telepresence Robot

Abdul Al-Khodairy. *Suva*





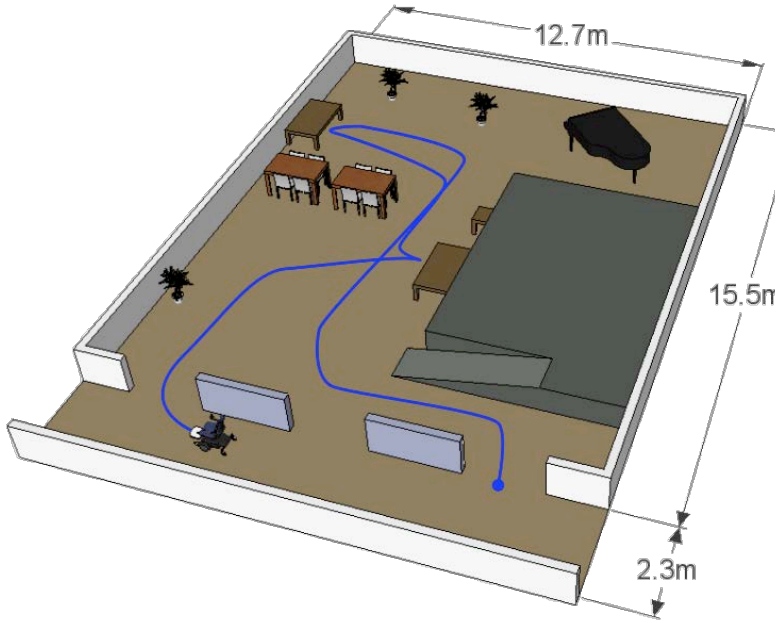
Time	Mental / Manual
s1-s4	1.15
d1-d6	1.16 (1.07)

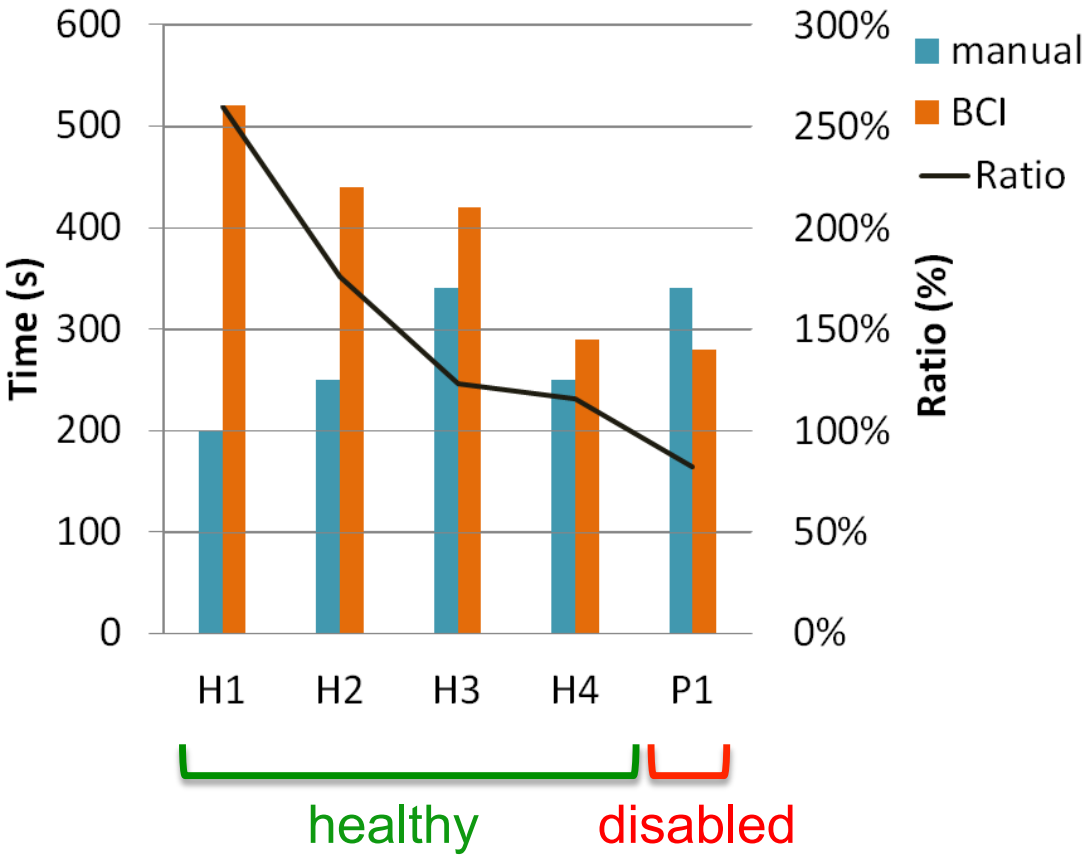
Com-mands	Mental / Manual
s1-s4	1.00
d1-d6	0.90 (0.75)

Brain-controlled Wheelchair

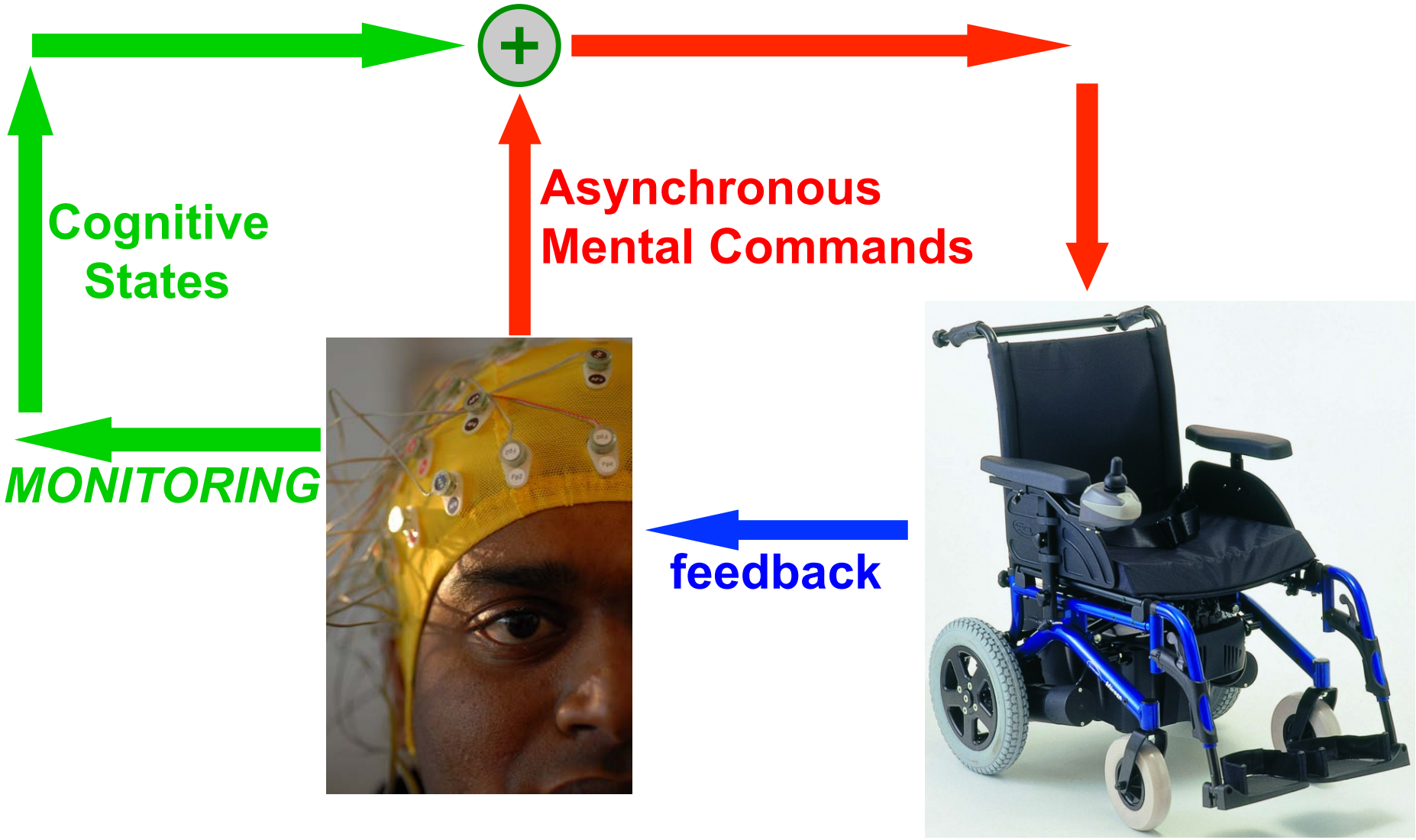
Drive along route

Dock and pause at 2 tables

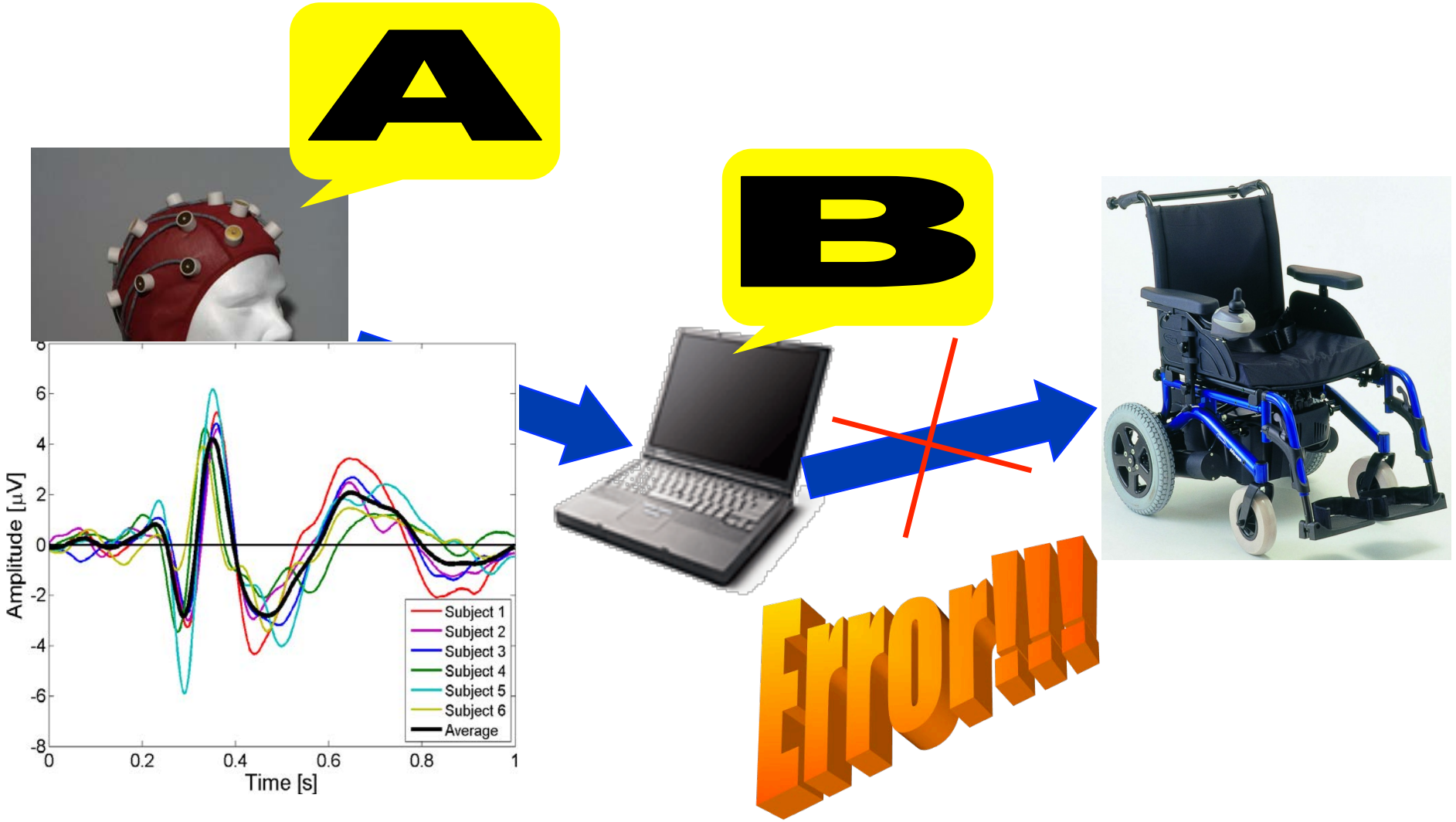




Cognitive States: Human in the Loop

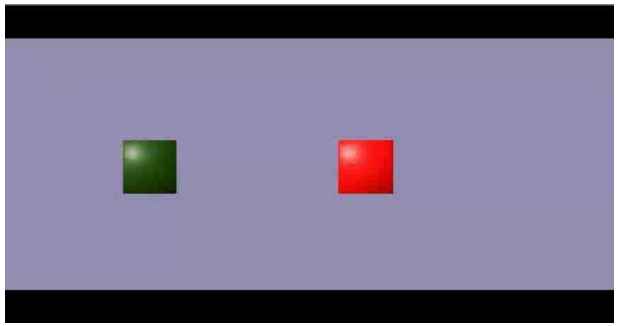


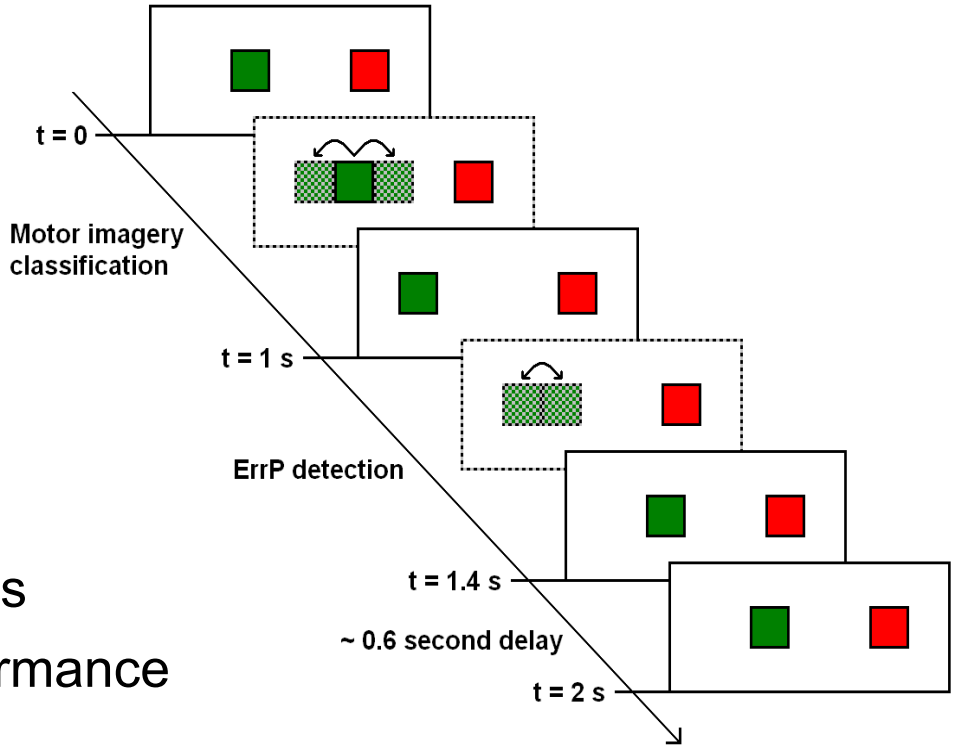
Cognitive States: Error Recognition



ErrP: Online Implementation

Pierre Ferrez





- Two naïve subjects
- Two different days
- 150 ms window: 250 → 400 ms
- Above 200% increase in performance (Bits per Trial)

Conclusions

➔ **Fast** & **timing decision-making** is critical

➔ How to bridge the **cognitive gap?**

- ***Shared control*** — Principled approaches to blend user's mental capabilities and device's intelligence
- ***Natural interaction*** — Support Multitasking and Intentional Non-Control
- ***Brain signals carry cognitive information*** — Cognitive States modulate interaction

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- L. Tonin

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tools for brain-computer interaction

robotics
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