Neuro-adaptive technology for Human System Interaction
Improving Human-Machine Teaming
APPROACH

Future Neuroimaging
Continuous & ubiquitous in daily life

Neuroergonomic Research Spectrum

Ultra-mobile Neuroimaging
Mobile Neuroimaging
Wearable Neuroimaging
Traditional Neuroimaging
Low-fidelity simulator / office settings
High-fidelity simulator / realistic settings
Actual task / real settings

Highly controlled & restricted settings
Team achievements

Durantin, et al., HBM (2017)

Dehais, et al., BBR (2019)

Callan, et al., HBM (2018)
Passive Brain-Computer Interfaces

To supplement or enhance

Signal processing

Preprocessing → Feature extraction → Translation

Signal acquisition → Commands → Automated decision system

Neurofeedback → Adaptation

Implicit modification of the interaction based on physiological features (cerebral, or hybrid with cardiac and ocular)

Small dataset and transfer learning issues

Denoising (ASR, ICA) & signal conditioning to enhance SNR (e.g. spatial filtering)

Feature Extraction: Temporal (event-related potentials), spectral (power in α), connectivity metrics (corr, covar, path length, Granger, etc)

ANITI Journées scientifiques 2019
Passive Brain-Computer Interfaces: Team achievements

Inattentational deafness detection accuracy: 72%
Canonical Correlation Analysis Spatial Patterns

Sparce Representation for Classification (SRC)
Sparce and Dense Representation (SDR)

Inter-subject classification accuracy: 67%

<table>
<thead>
<tr>
<th>Methods</th>
<th>Features</th>
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<tbody>
<tr>
<td></td>
<td>Delta</td>
</tr>
<tr>
<td>1-NN</td>
<td>59.08 ± 3.29</td>
</tr>
<tr>
<td>LDA</td>
<td>60.20 ± 4.15</td>
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<tr>
<td>sLDA</td>
<td>60.75 ± 3.64</td>
</tr>
<tr>
<td>SDR</td>
<td>61.50 ± 3.50</td>
</tr>
<tr>
<td>SRC</td>
<td>65.60 ± 4.02</td>
</tr>
</tbody>
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Dehais, et al., BBR (2019)
Dehais, et al., IEEE SMC (2019)
Mixed-Initiative Human-Machine Interaction

(Jiang and Arkin, 2015) have defined MI-HRI is a collaboration strategy for human-robot teams where humans and robots opportunistically seize (relinquish) initiative from (to) each other as a mission is being executed.

Human operators are not providential agents

**Issue**: strategy computation taking into account the (non-deterministic) human operator behavior and the partial observability of her/his state

**Challenges**:
→ interaction data acquisition (Charles et al., 2018)
→ human (belief) state and system state assessment (Régis et al., 2014)
→ sequential-decision making problem modeling, solving and evaluation (de Souza et al. 2015, Gateau et al., 2016)
Team achievements


Team achievements

HoRlzON: driving human-robot interaction
→ Crowdsourcing platform robot-isae.isae.fr
→ Lab experiments for physiological data acquisition (cardiac activity)


PhD 1: Modelling the dynamics of multimodal attention

Selective attention
• Enhancement of Task Relevant Networks.
• Alteration in Effective Connectivity by Modulation of Neural Synchrony: Gamma (>40 Hz) Theta (4-8 Hz)
• Cross-Frequency Coupling

Focused attention
• Suppression of Non-Primary Task Relevant Networks.
• Increased Alpha (8-14 Hz) in Non-Primary Task Networks
• Change in Theta (4-8 Hz) and Gamma (>40Hz) band power in Primary Task Networks


→ Understanding: inverse model-based RL

→ Online monitoring
PhD 2 + Post doc 1: Robust BCI pipeline

Benchmarking & development
• Feature extraction, signal conditioning & machine learning methods (e.g. use of Riemannian geometry)
• Transfer learning & ecological settings (e.g. adaptive techniques)
• Mental states and/or features overlap → online adaptive methods

Applied to active & passive BCI applications
• Applied to active & passive BCI applications
• Databases: public & our own

→ Focus on signal conditioning and classification techniques to improve online mental state estimation wrt cross-subject, cross-task, cross-setting and cross-session variability
Post Doc 2: Automated Human-System Interaction model learning and planning

→ Optimal model learning based on demonstrations
  - sequential decision-making under uncertainty framework (PO)MDP
  - Automated system state aggregation and variable selection

→ Resulting model as a compromise between:
  - The precision of model parameters
  - and policy optimizability (model accuracy prevented by the curse of dimensionality)

→ Model learning for planning approach evaluation using available datasets of HRI/HSI experiments

→ Resulting policy evaluation in ecological experiments
“NEURO-IA” Master of science (140 hours) – for “ingénieur.e.s supaéro”

Start: fall 2020

4 modules:

- **M1** - Neuroergonomics (45h): Neurosciences, Human Factor, HMI design.
- **M2** – Brain Computer Interface (30h): Sensors, Signal processing, experimental method
- **M3** – Tools and methods for Neuroergonomics (40h): Machine-learning, Deterministic and Non-deterministic Planning, Multi agent systems, Games theory,
- **M4** – Research & Development project (25h):