ANITI

ARTIFICIAL & NATURAL INTELLIGENCE
TOULOUSE INSTITUTE

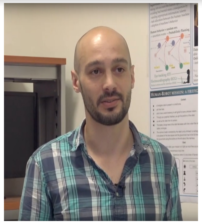
Neuro-adaptive technology for Human System Interaction

Université Fédérale
Toulouse Midi-Pyrénées

F. DEHAIS
Neuroergonomics
ISAE

R. ROY
Signal Processing
ISAE

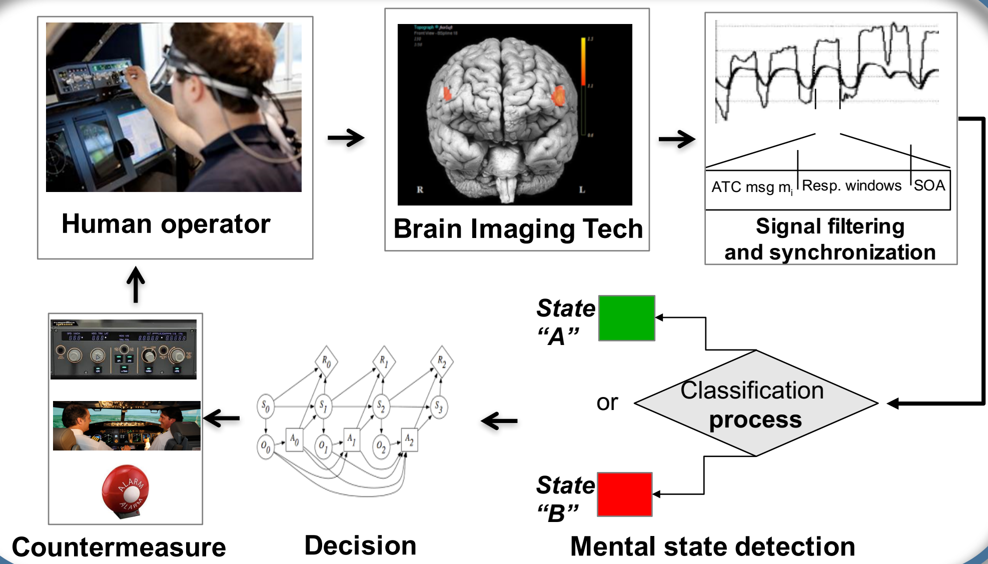
C. CHANEL
AI/Planning
ISAE



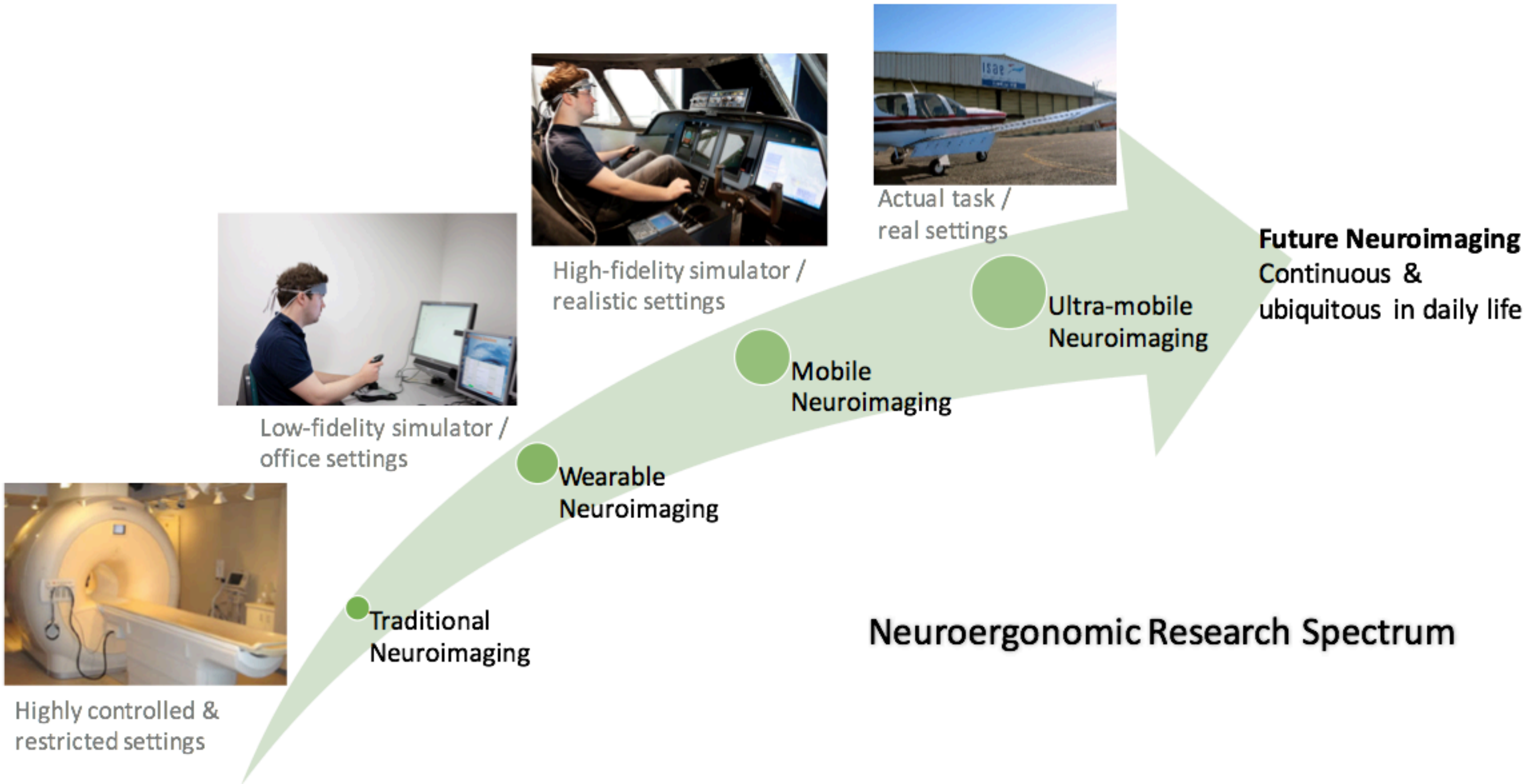
N. DROUGARD
Machine learning
ISAE

F. LOTTE
BCI
INRIA Bordeaux

Improving Human-Machine Teaming



APPROACH


Actual task /
real settings
High-fidelity simulator /
realistic settings
Low-fidelity simulator /
office settings
Highly controlled &
restricted settings
Traditional
Neuroimaging
Wearable
Neuroimaging
Mobile
Neuroimaging
Ultra-mobile
Neuroimaging
Future Neuroimaging
Continuous &
ubiquitous in daily life
Neuroergonomic Research Spectrum

Team achievements

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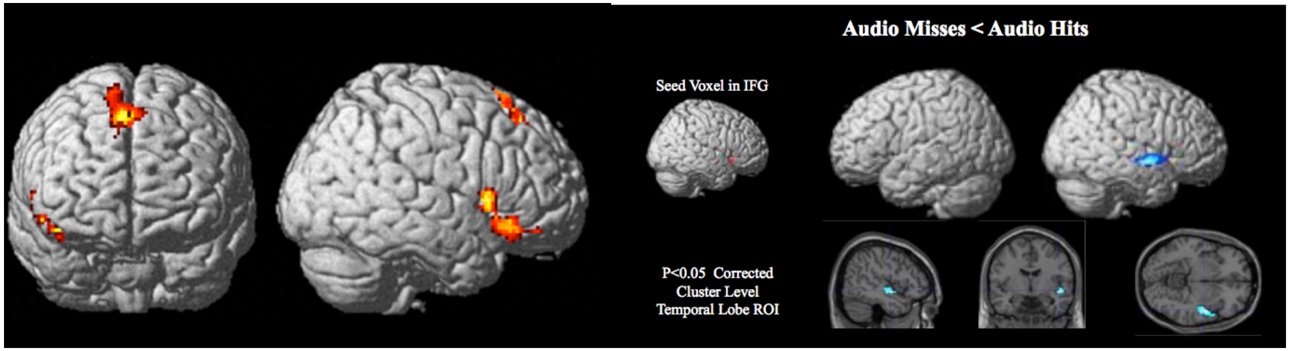
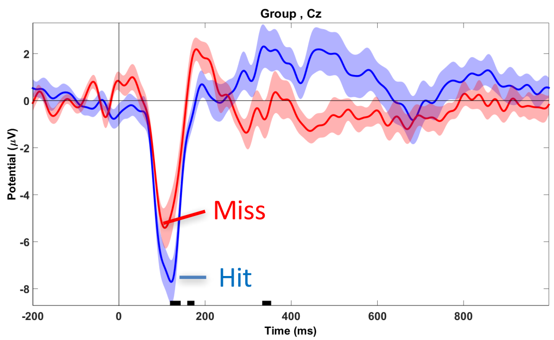
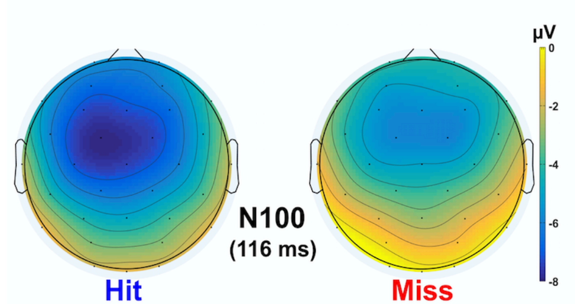
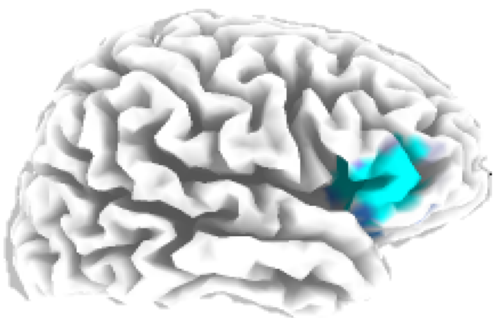


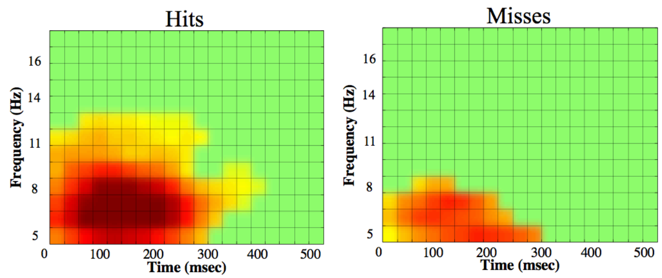
Durantin, et al., HBM (2017)





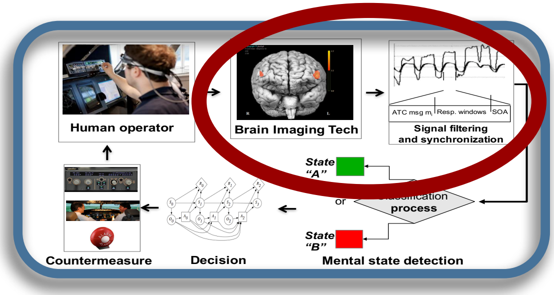
Dehais, et al., BBR (2019)



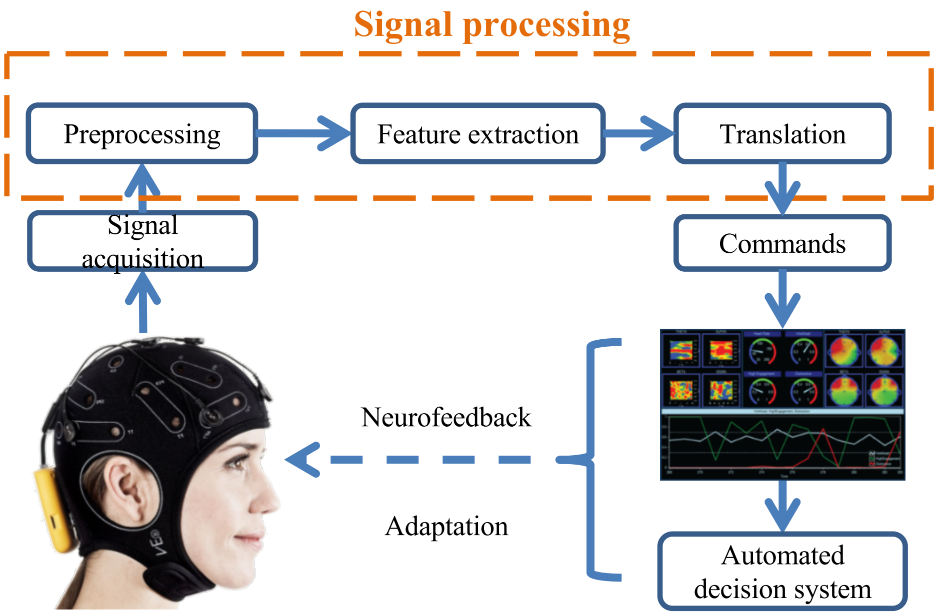


Callan, et al., HBM (2018)

Passive Brain-Computer Interfaces



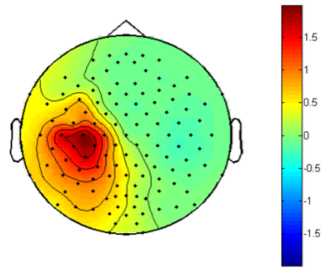
To supplement or enhance

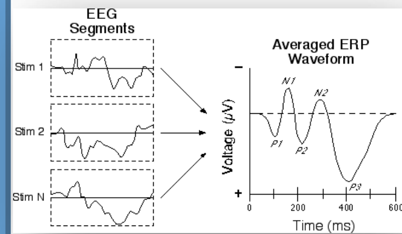


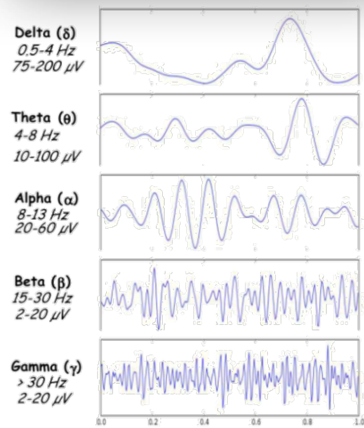
Small dataset and tranfer learning issues

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)

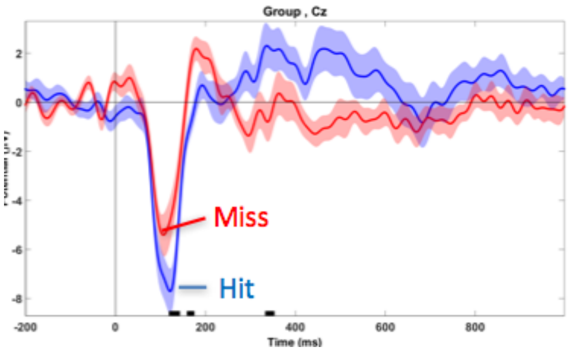


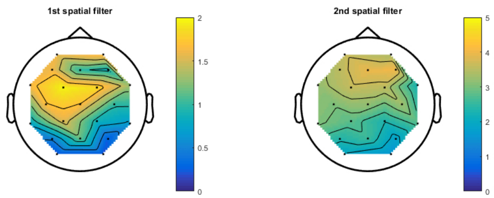




Implicit modification of the interaction based on physiological features (cerebral, or hybrid with cardiac and ocular)

Passive Brain-Computer Interfaces: Team achievements

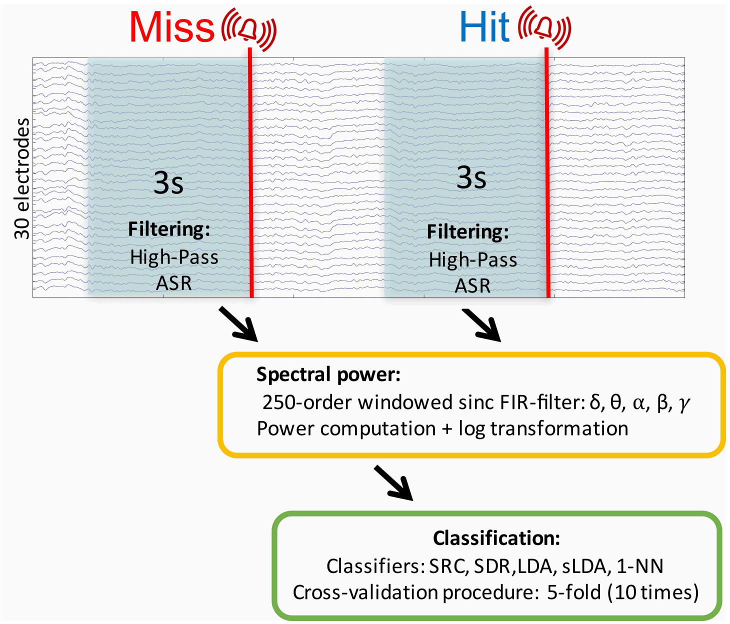




Canonical Correlation Analysis Spatial Patterns

Inattentional deafness detection accuracy: 72%

Dehais, et al., BBR (2019)



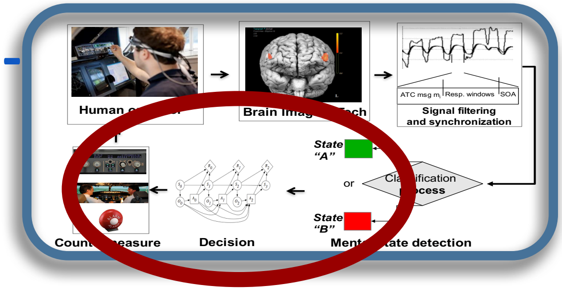
Sparce Representation for Classification (SRC)
Sparce and Dense Representation (SDR)

Inter-subject classification accuracy: 67%

Methods	Features						
	Delta	Theta	Alpha	Beta	Gamma	Engagement	Fusion
1-NN	59.08 ± 3.29	57.29 ± 2.85	57.38 ± 4.06	58.21 ± 2.15	59.50 ± 3.01	58.04 ± 1.76	59.60 ± 2.70
LDA	60.20 ± 4.15	59.60 ± 2.79	58.71 ± 2.25	58.67 ± 3.06	58.50 ± 3.60	62.20 ± 2.50	60.60 ± 4.00
sLDA	60.75 ± 3.64	54.38 ± 3.45	53.38 ± 3.13	53.96 ± 3.20	56.25 ± 2.56	59.25 ± 3.33	60.00 ± 3.07
SDR	61.50 ± 3.50	62.60 ± 2.80	60.50 ± 1.80	60.40 ± 1.80	58.90 ± 1.60	62.50 ± 3.07	65.40 ± 2.80
SRC	65.60 ± 4.02	64.58 ± 2.25	63.83 ± 3.37	63.96 ± 3.42	64.08 ± 3.78	63.58 ± 2.94	66.90 ± 3.10

Dehais, et al., IEEE SMC (2019)

Mixed-Initiative Human-Machine Interaction



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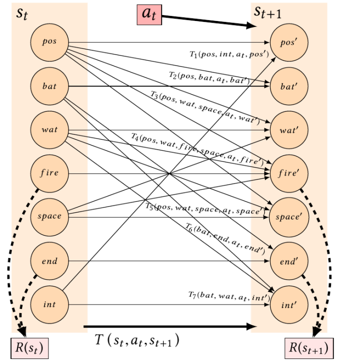
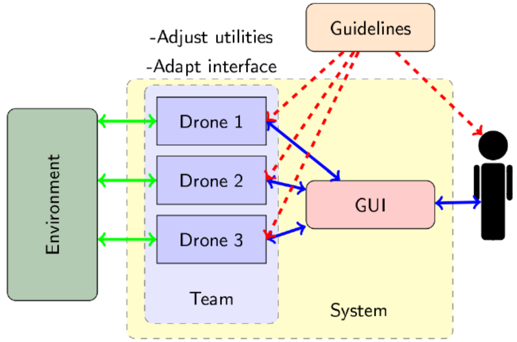
(Jiang and Arkin, 2015) have defined MI-HRI is a collaboration strategy for human-robot teams where humans and robots opportunistically seize (relinquish) initiative from (to) each other as a mission is being executed.

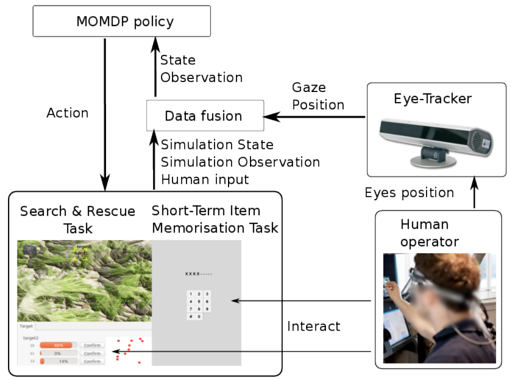


Human operators are not providential agents

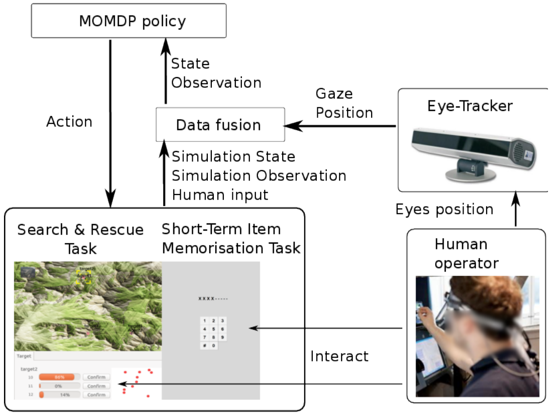


Issue : strategy computation taking into account the (non-deterministic) human operator behavior and the partial observability of her/his state

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)



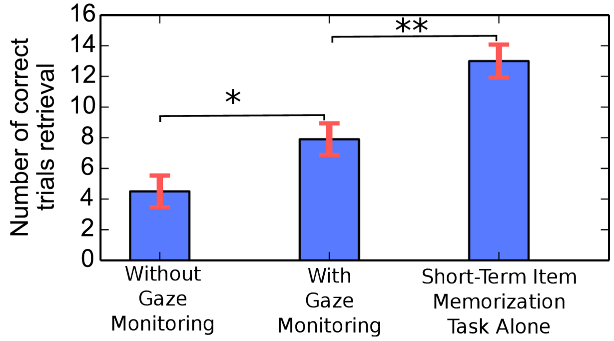
Team achievements



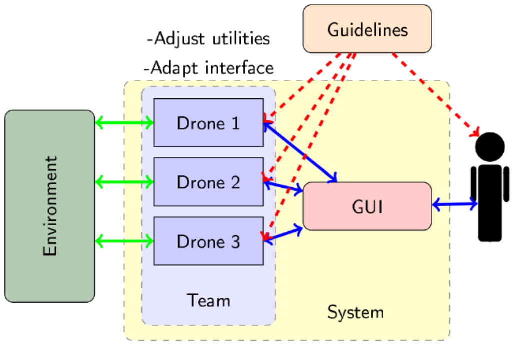
Metric	Request ratio score	Averaged expected rewards
without GM	0.76 (0.26)	1321.4 (456.5)
with GM	0.84 (0.11)	1210.4 (269.5)
S&R task alone	0.92 (0.03)	1143.4 (469.9)

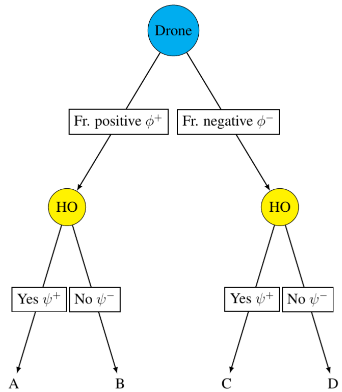
TABLE II

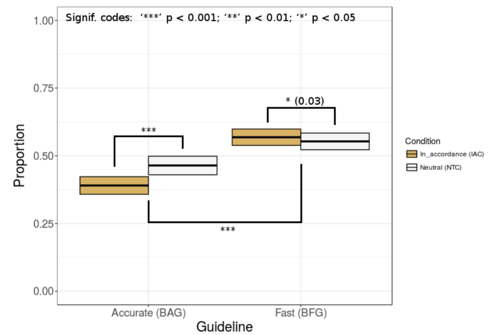
Search & Rescue TASK'S AVERAGED SCORES (AND STD).



(2016) Thibault Gateau, Caroline P. Carvalho Chanel, Mai-Huy Le and Frédéric Dehais.
Considering Human's Non-Deterministic Behavior and his Availability State When Designing a Collaborative Human-Robots System
In Proceeding of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2016)







Ulbadino de Souza, P.E. and Carvalho Chanel, C.P and Dehais, F. and Givigi, S.
Towards human-robot interaction: a framing effect experiment.
(2016) In Proceedings of the IEEE International Conference on Systems, Man, and Cybernetics.

Ulbadino de Souza, P.E. and Carvalho Chanel, C.P and Dehais, F. and Givigi, S.
A Game Theoretical Formulation of a Decentralized Cooperative Multi-Agent Surveillance Mission.
(2016) 4th Workshop on Distributed and Multi-Agent Planning.

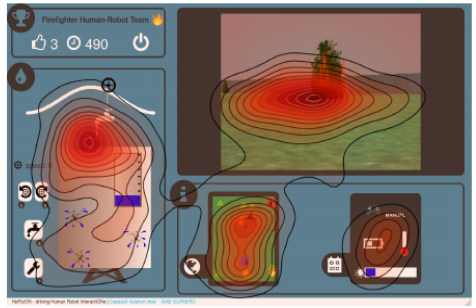
Team achievements

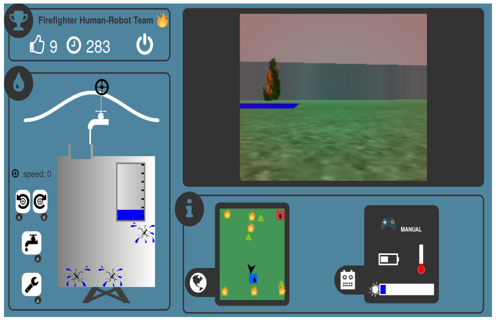
HoRIzON: driving human-robot interaction

→ Crowdsourcing platform

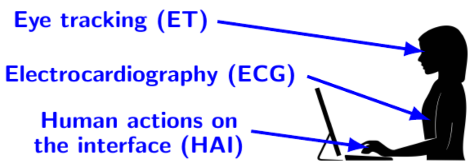
robot-isae.isae.fr

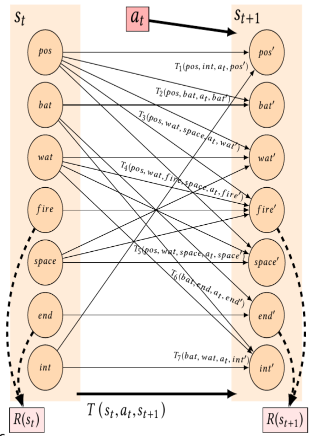
→ Lab experiments for physiological data acquisition (cardiac activity)

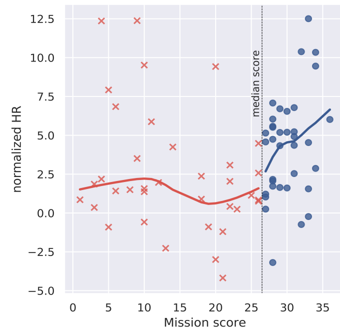


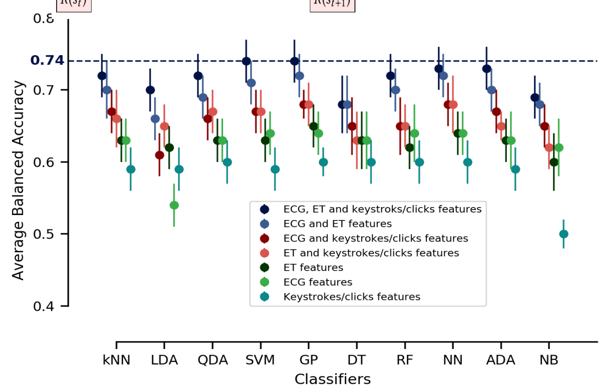


Robot Firefighter Mission







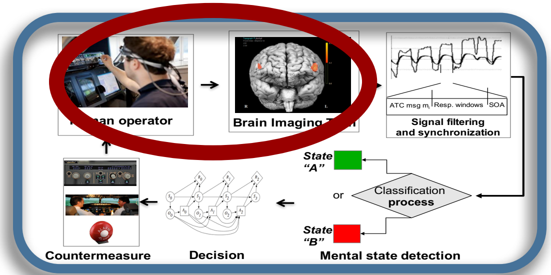


Performance Prediction Balanced Accuracy Results

Charles, J. and Chanel, C.P.C and Chauffaut, C. and Chauvin, P. and Drougard, N.
Human-Agent Interaction Model Learning based on Crowdsourcing.
(2018) In: 6th International Conference on Human- Agent Interaction (HAI'18)

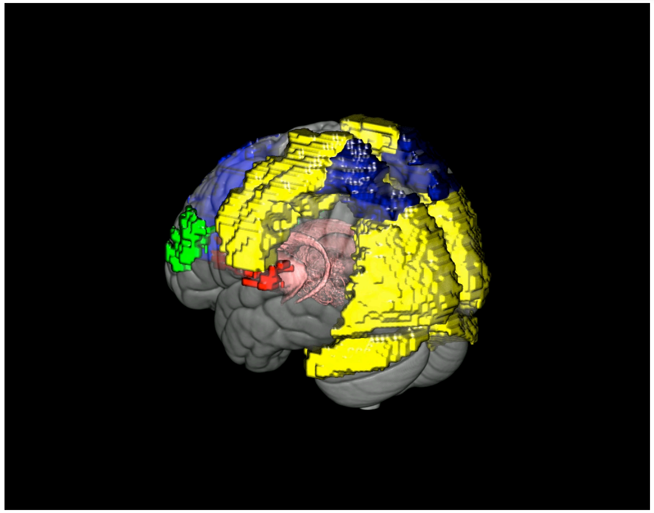
Chanel, C.P.C and Roy, R.N and Dehais, F. and Drougard, N.
Towards MI-HRI: Assessment of Physiological and Behavioral Features for performance prediction
(2019) Under revision.

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

Clayton et al. (2015); Buchman et al (2007, 2015)

→ Understanding: inverse model-based RL

→ Online monitoring

UC San Diego

CiNet

Daniel Callan

PhD 2 + Post doc 1: **Robust BCI pipeline**

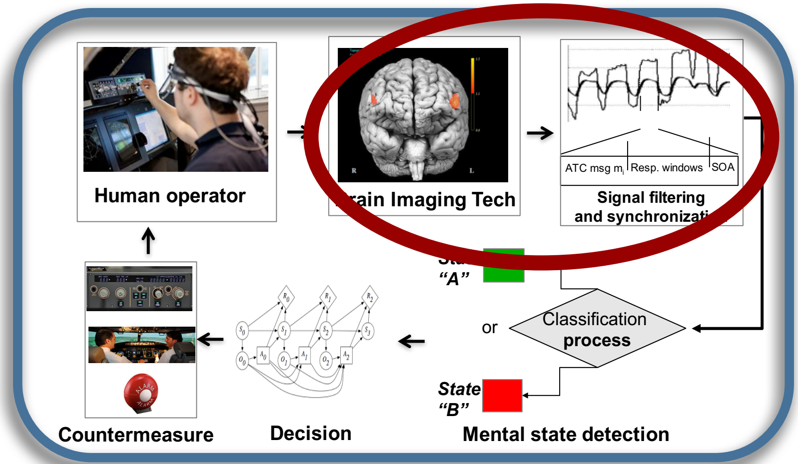
Benchmarking & development

- 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

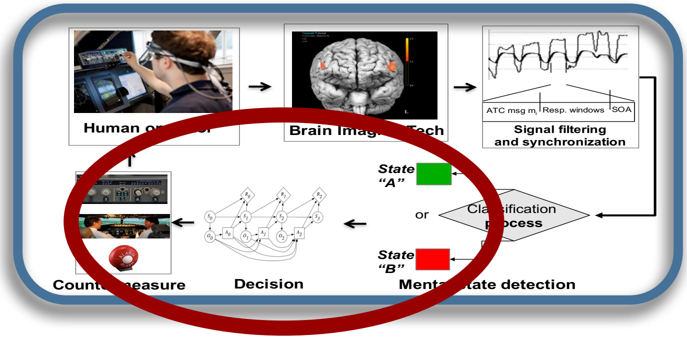


Short stays at INIRIA Bordeaux with Dr F Lotte

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

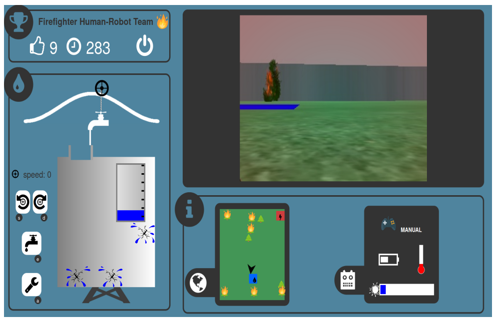


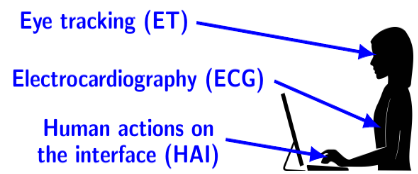
Mixed-Initiative Interaction learning and planning

→ Resulting model as a compromise between:

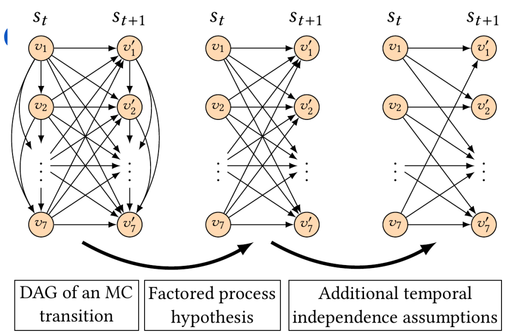
- The precision of model parameters
- and policy optimizability

(model accuracy prevented by the curse of dimensionality)





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



→ Resulting policy evaluation in ecological experiments

Teaching

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"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):**