Human factors in aerospace: why and how to measure them

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What are the human factors (HF) ?

Why it is so important to measure HF

- Over **1.2 million people die each year on the world's roads**, with millions more sustaining serious injuries and living with long-term adverse health consequences. **Human error is the main cause** of the 57 % of road accidents and a contributing factor in over 90 % of them.
- More than **70% of aviation accidents are due to human errors**, most of them caused by pilots' overload or mental status impairment.
- **Medical errors cause high people mortality**, about 100.000 people per year. Furthermore, about the 10 % oh hospitalized patients experienced complications on their treatments due to medical mistakes.

The Human Factor is the most important but the less controllable factor in operational environments.

(Boeing Report, 2011), (Feyer and Williamson, 2011), (WHO Report, 2015)

Why it is so important to measure HF in space?

- It has been suggested that variation of gravity from 1g generated temporary diminution of decision-making capabilities in astronauts.
- Distribution of fluids impairs the regular cerebral rhythms in EEG on astronauts.
- For long term missions while the psychologic tests have been already attempted in the field, trainers still waiting a device able to measure **objectively** such human factors in **real time**.

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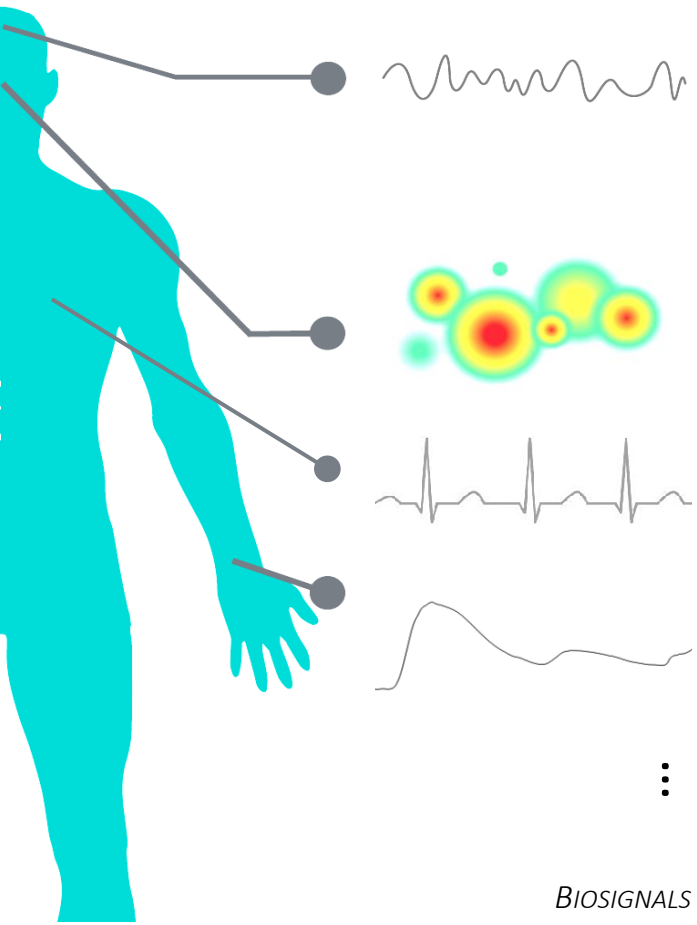
How to measure HF: to use cognitive neuroscience and beyond state of the art devices



EEG

EYES GAZE

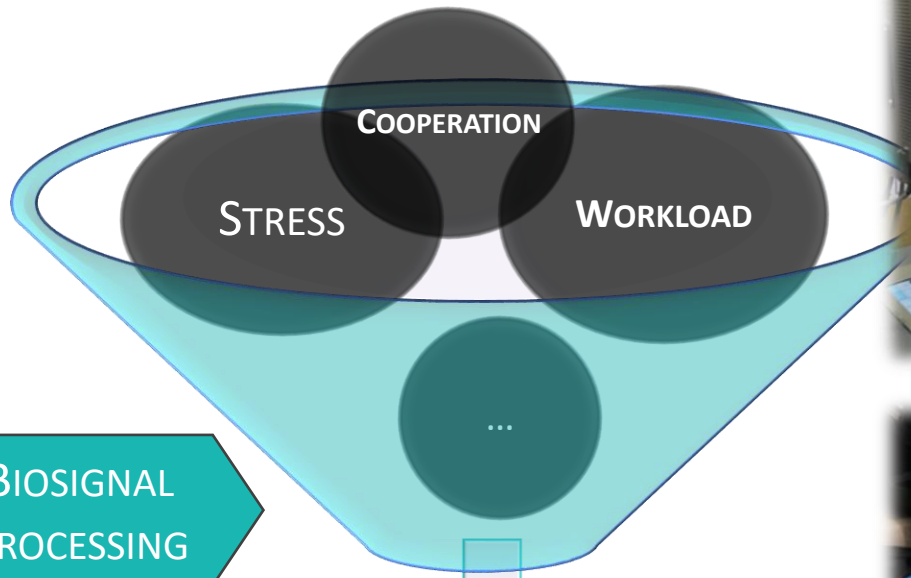
ECG

GSR

⋮

BIOSIGNALS

BIOSIGNAL PROCESSING



OPERATOR'S PSYCHOPHYSIOLOGICAL STATE

Neurophysiological metrics of Human Factor Components

NEUROMETRICS

Indexes based on neurophysiological signals

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How to do that in real environments: the two needed advancements

- **1) To realize portable and easy-to-use** cerebral measurements devices to be used during training without interfere with normal practices
- **2) To measure** efficiently and in a scientific way the main neuro-metrics associated with relevant mental states (e.g. stress, mental workload, etc).

A project funded by EU H2020 - FTI GA 950998

With whom the research have been made: science and technologies have been developed with different aeronautic partners along a decade

What We Achieved So Far

Methodologies for:

- Training assessment
- Skill level (S-R-K model) assessment
- Mental states evaluation
- Systems testing and comparison
- Cooperation between brains (CRM\TRM)
- Adaptive Automations

Tested ON:

- **Professional a\c commercial and military pilots**
  (total sample size 45 users)
- **Professional helicopters military pilots**
  (total sample size 5 users)
- **ATCOs professional and students**
  (more than 100 users)
- **Car drivers**
  (total sample size 70 users)
- **Surgeons**
  (total sample size 30 users)
- **Sky Divers**
  (total sample size 12 users)

Collaborations with:

National/International research projects

More than 60 publications since 2009, an European Patent for the mental workload evaluation and several international awards

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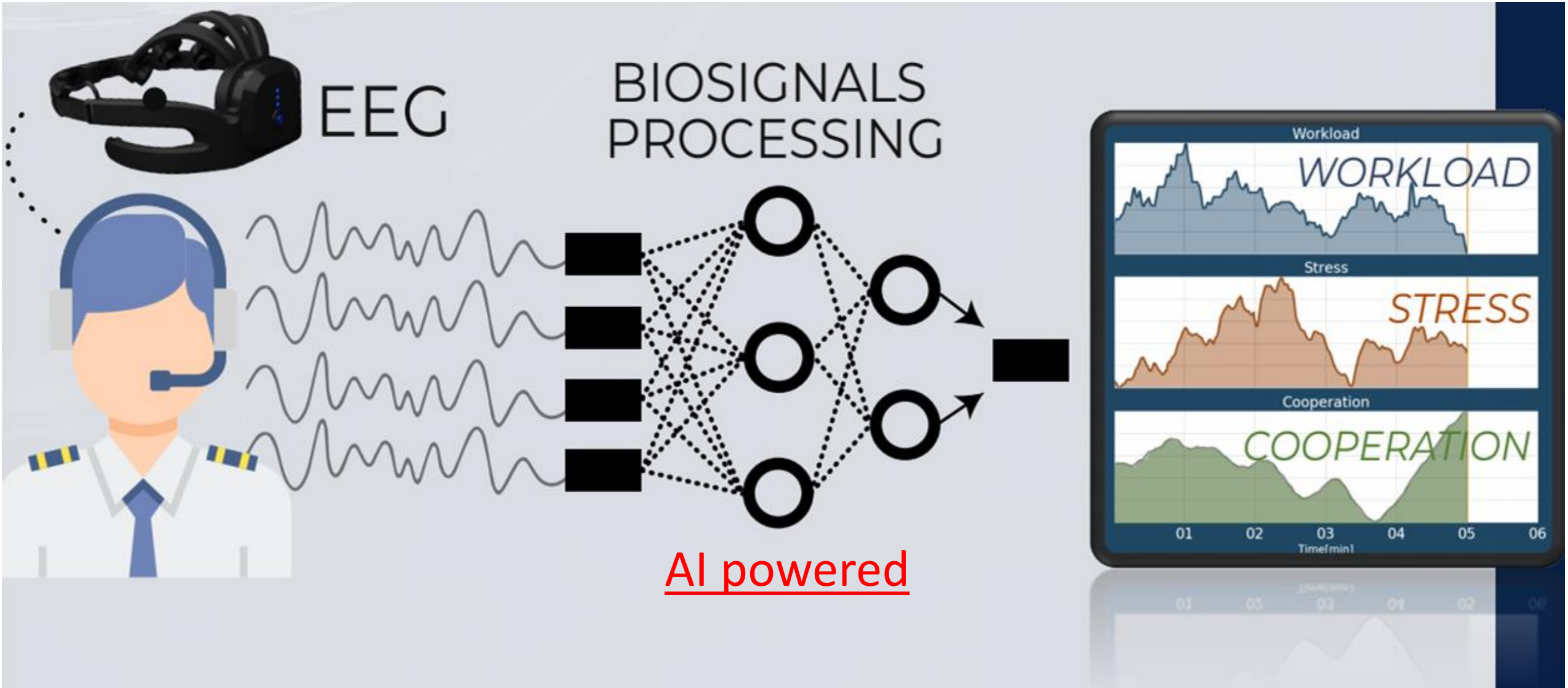
The estimates of neuro-metrics in airplane pilots or Air Traffic Controllers



AI powered

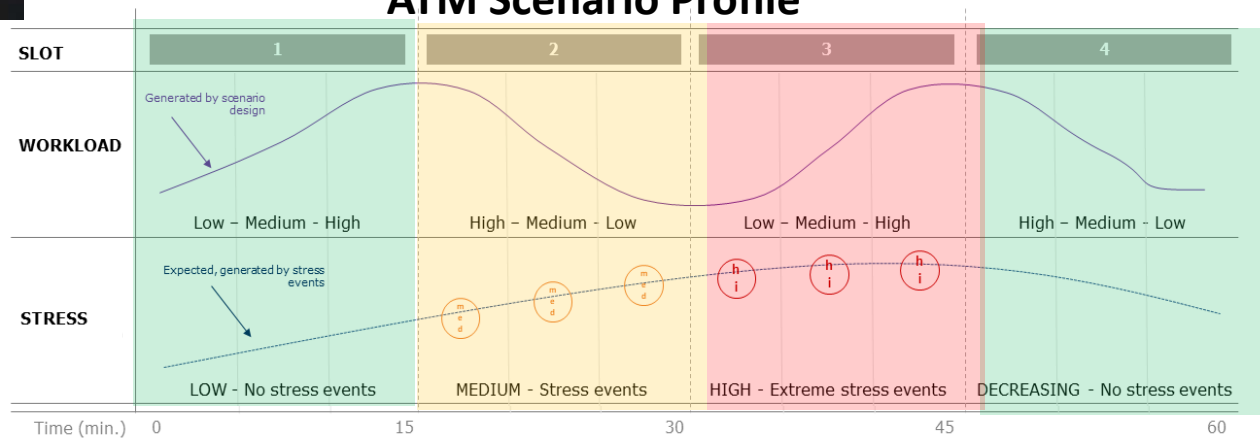
Reading the mental fatigue in air traffic controllers at work

Credits: EU project STRESS - DeepBlue, Sapienza, Enac, 2018

ATCO's Stress Assessment

16 Studenti ATC
60-min Scenario ATM realistico
2 Subject Matter Experts (SMEs)
2 Pseudo-Piloti
Dati Neurofisiologici (EEG, ECG, GSR)
Self-report (Ogni 5 minuti)

ATM Scenario Profile



(Borghini et al., 2020, Nat Scient Rep)

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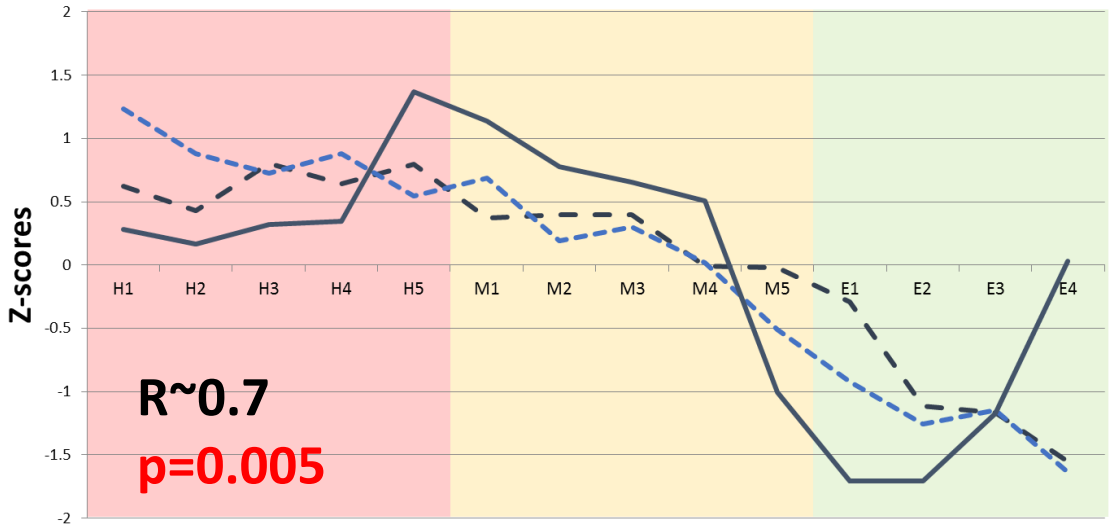
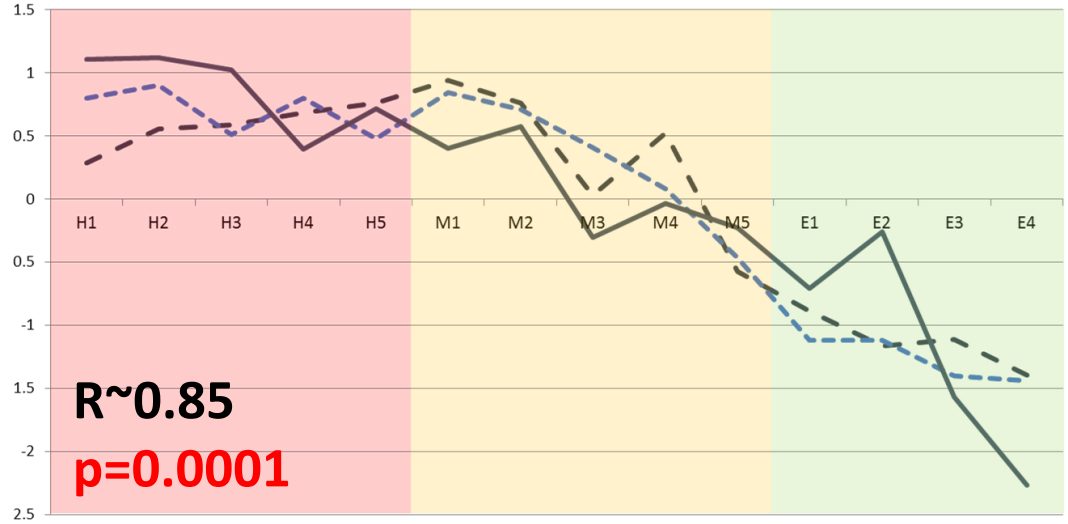
Example: ATM Case Study

ATC Experts



ATC Students



Difficulty level

ISA Score SME Score W_{EEG}

	Easy vs Medium	Medium vs Hard	Easy vs Hard
ATC Experts	**0.02**	**0.01**	**0.003**
ATC Students	**0.04**	**0.04**	**0.003**

(Aricò, Borghini et al., 2016 Prog Brain Res)

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MINDTOOTH project: Pilot experiment URBE

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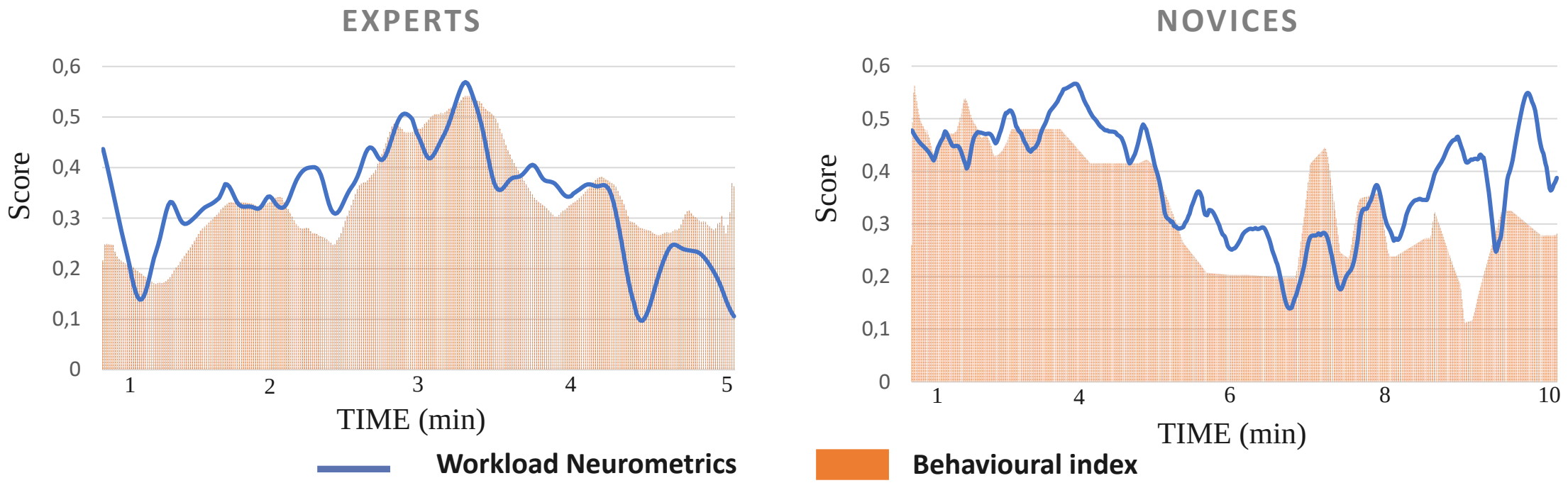
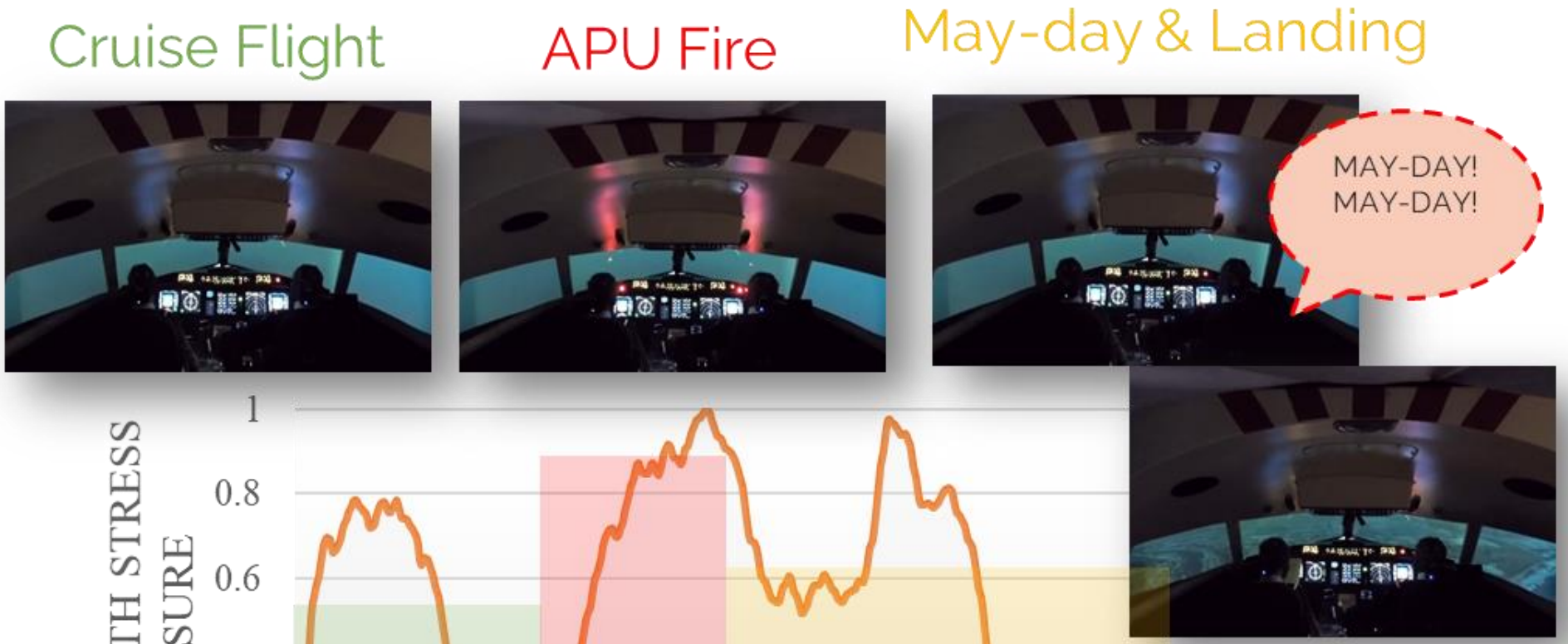
Workload index correlation during workload scenario for expert and novice pilots



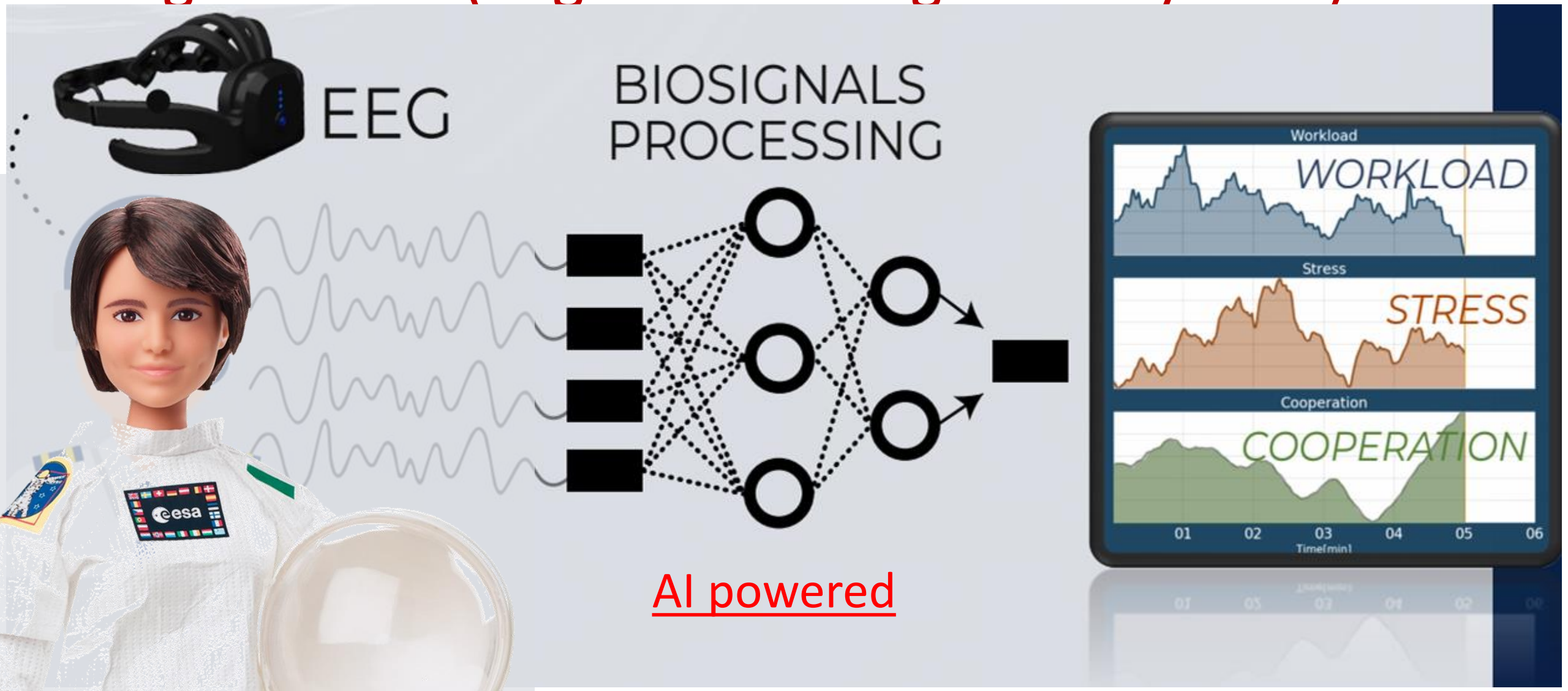
✓ The workload neurometric is correlated with behavioural index assessed by the trainers

Estimation of stress induced by dangerous situation in a pilot during airflight simulation



- ✓ **The Mindtooth Stress measure allows the identification of stressful behaviours**

The extension of neurometrics to space flights is then straightforward (Virgin Galactic flight in May 2023)



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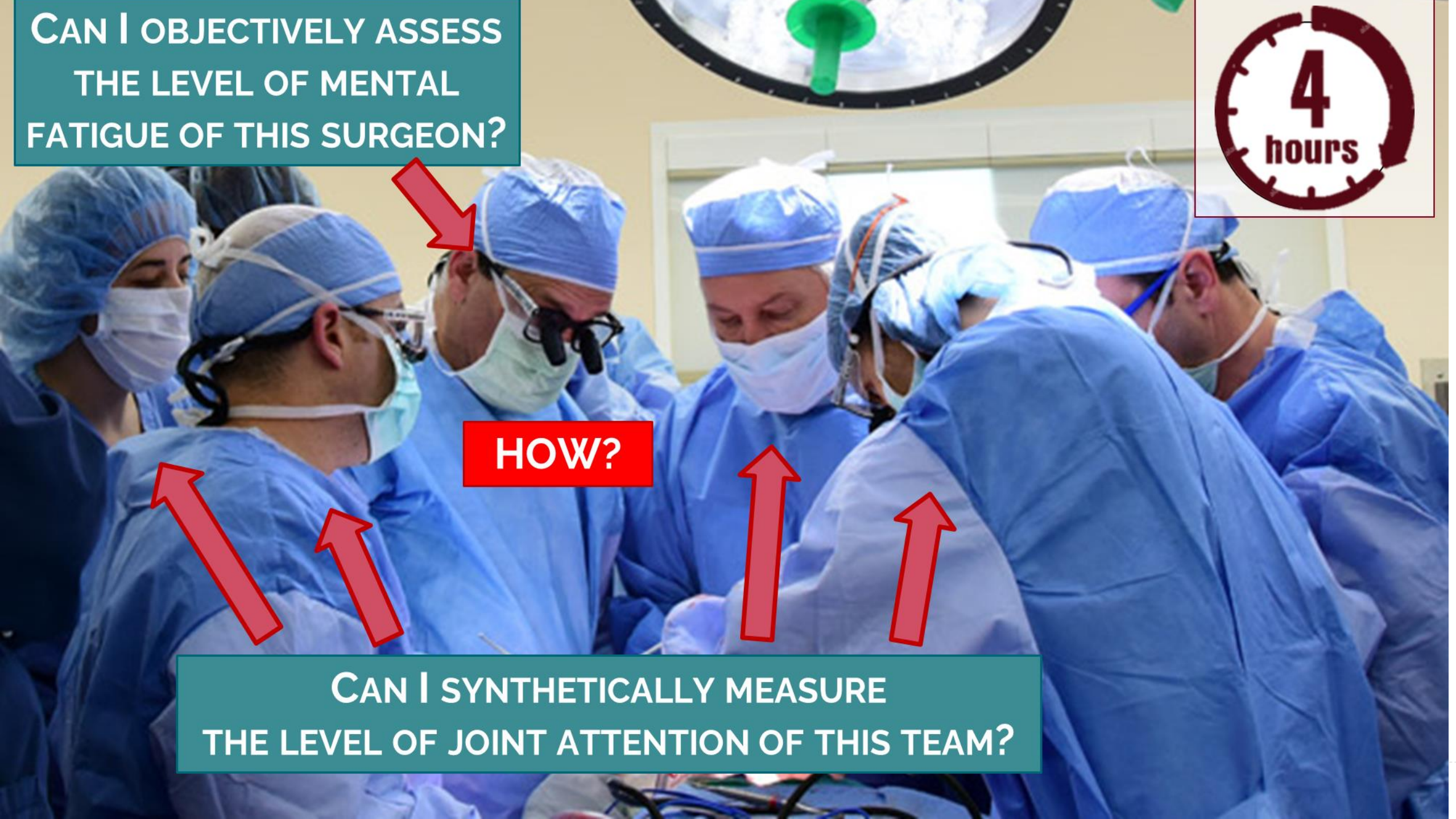
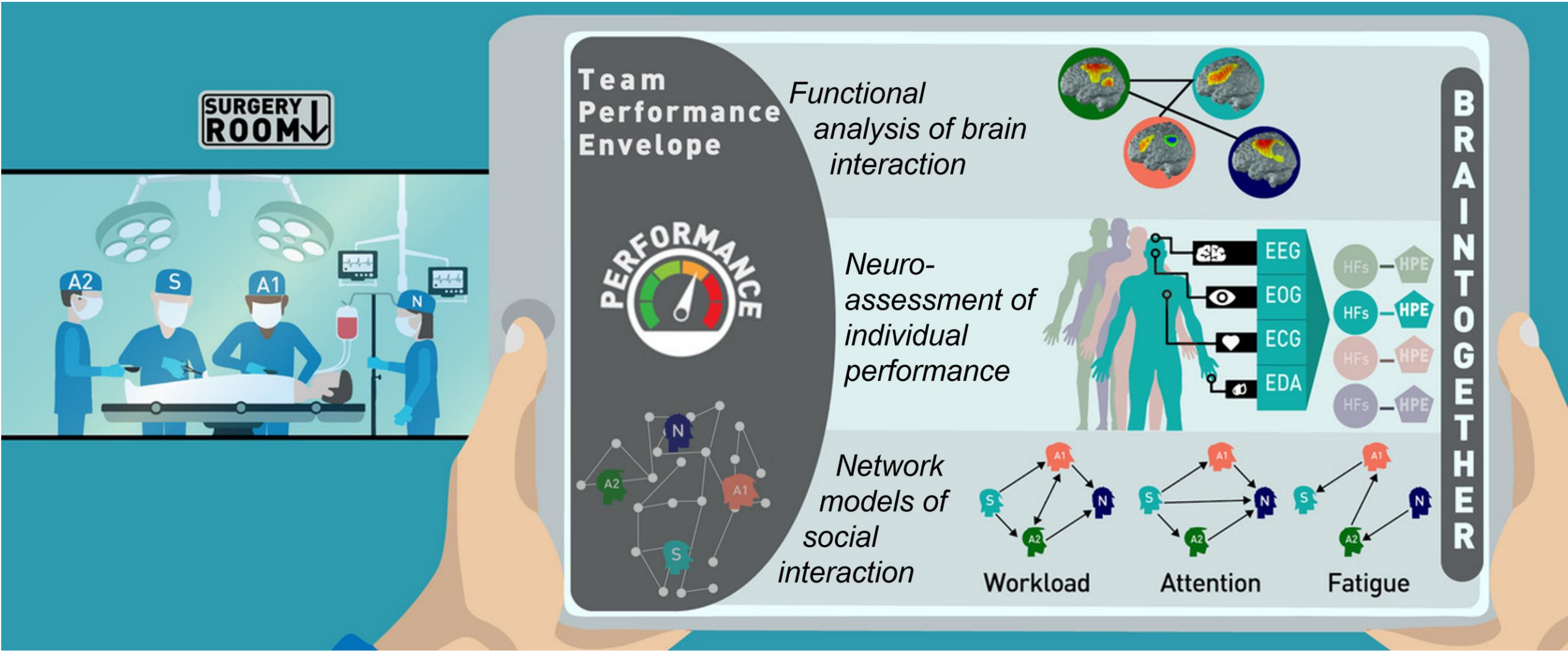

CAN I OBJECTIVELY ASSESS THE LEVEL OF MENTAL FATIGUE OF THIS SURGEON?
4 hours
HOW?
CAN I SYNTHETICALLY MEASURE THE LEVEL OF JOINT ATTENTION OF THIS TEAM?

The measuring of team cooperation



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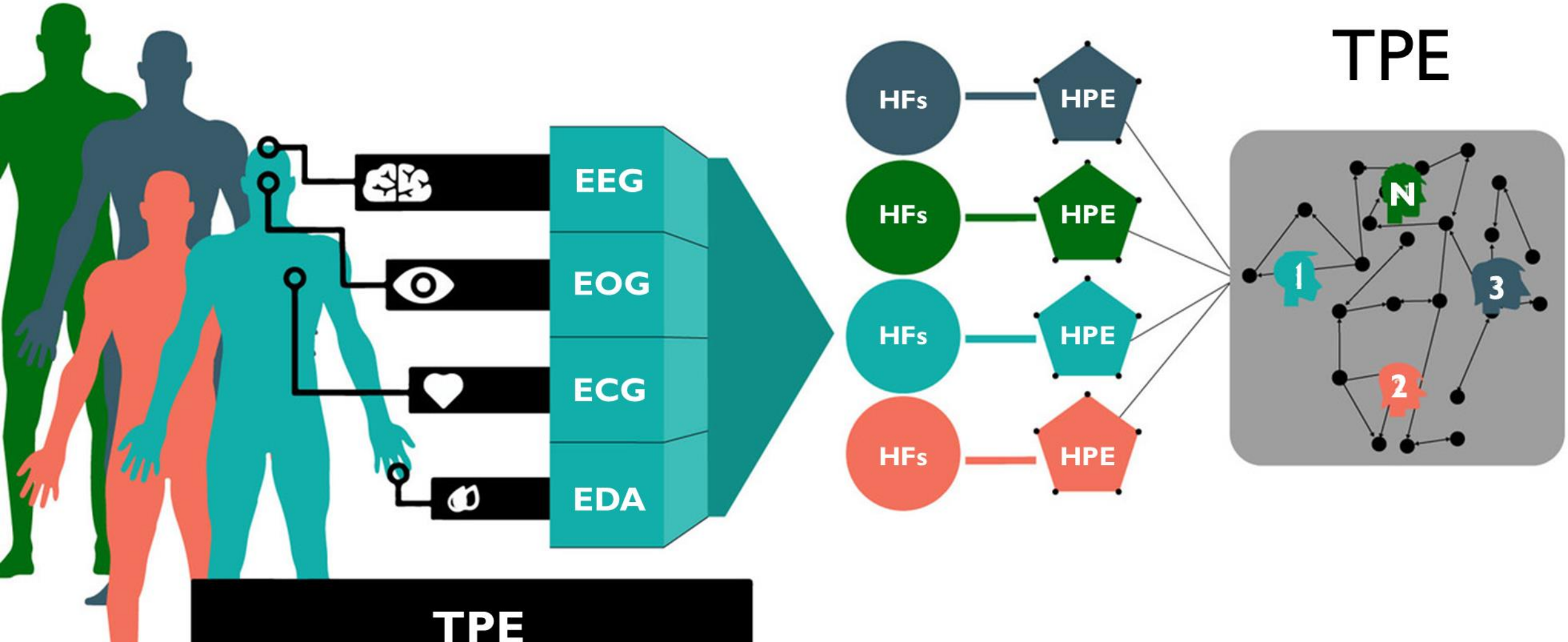
Assessing in real time the mind states of astronauts and their degree of cooperation by neurometrics measurements



HOW?
London $773
New York
Madrid $772
Rome
Catania $793
North Atlantic Ocean
Casablanca $1,086
Tenerife $1,489
CAN I OBJECTIVELY ASSESS THE DEGREE AND THE QUALITY OF THEIR COOPERATION?

2018

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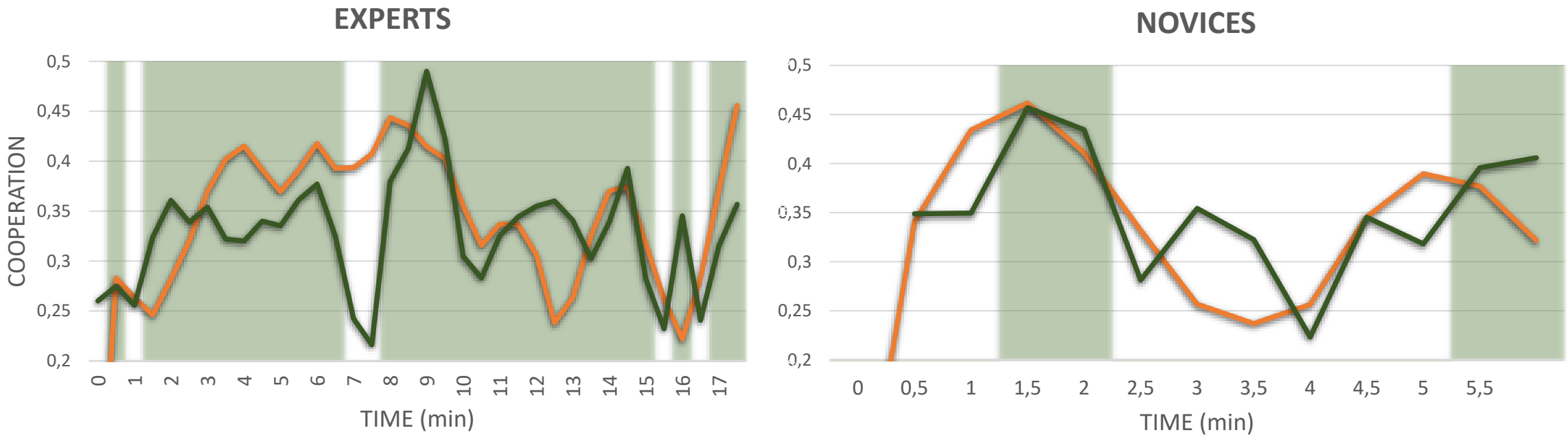
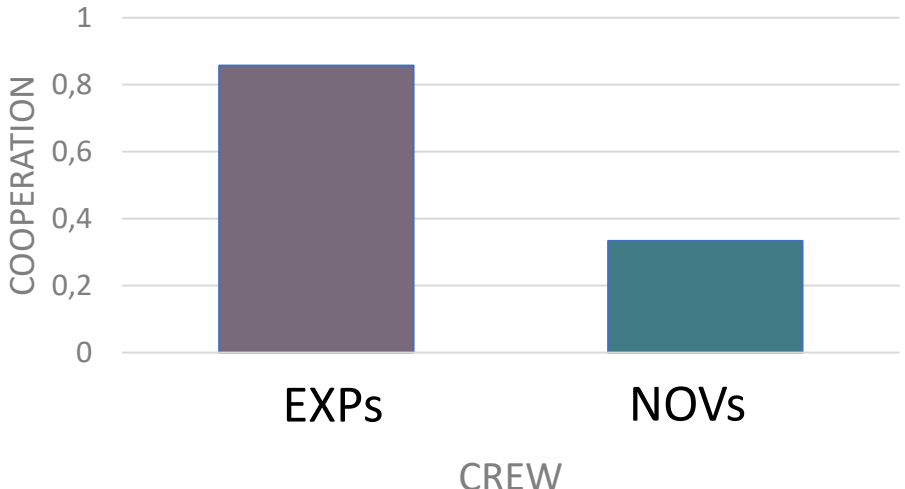
Cooperation index correlation estimated during pilot's training





Behavioural
Neurometric
Neurometric class*

- ✓ The Cooperation index is correlated with the behavioural score assessed by the trainers (Average among pilots).
- ✓ Moreover The cooperation of Expert Pilots was higher than that one of Novices.

The measuring of team cooperation

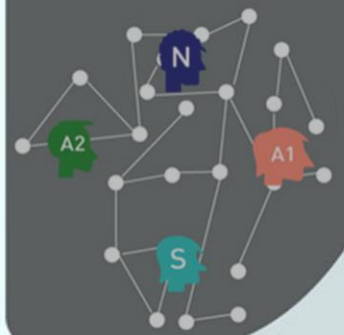
The measuring of team cooperation

Mission team

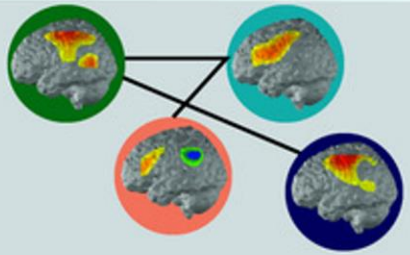
Team's Human Factors assessment in real time from remote

Team Performance Envelope

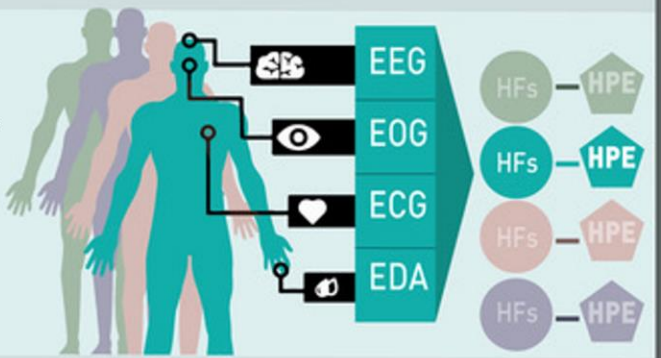
PERFORMANCE



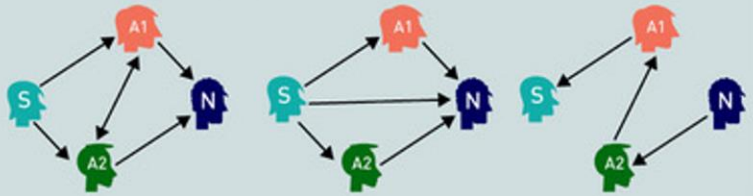
Functional analysis of brain interaction



Neuro-assessment of individual performance



Network models of social interaction



BRAINTOGETHER

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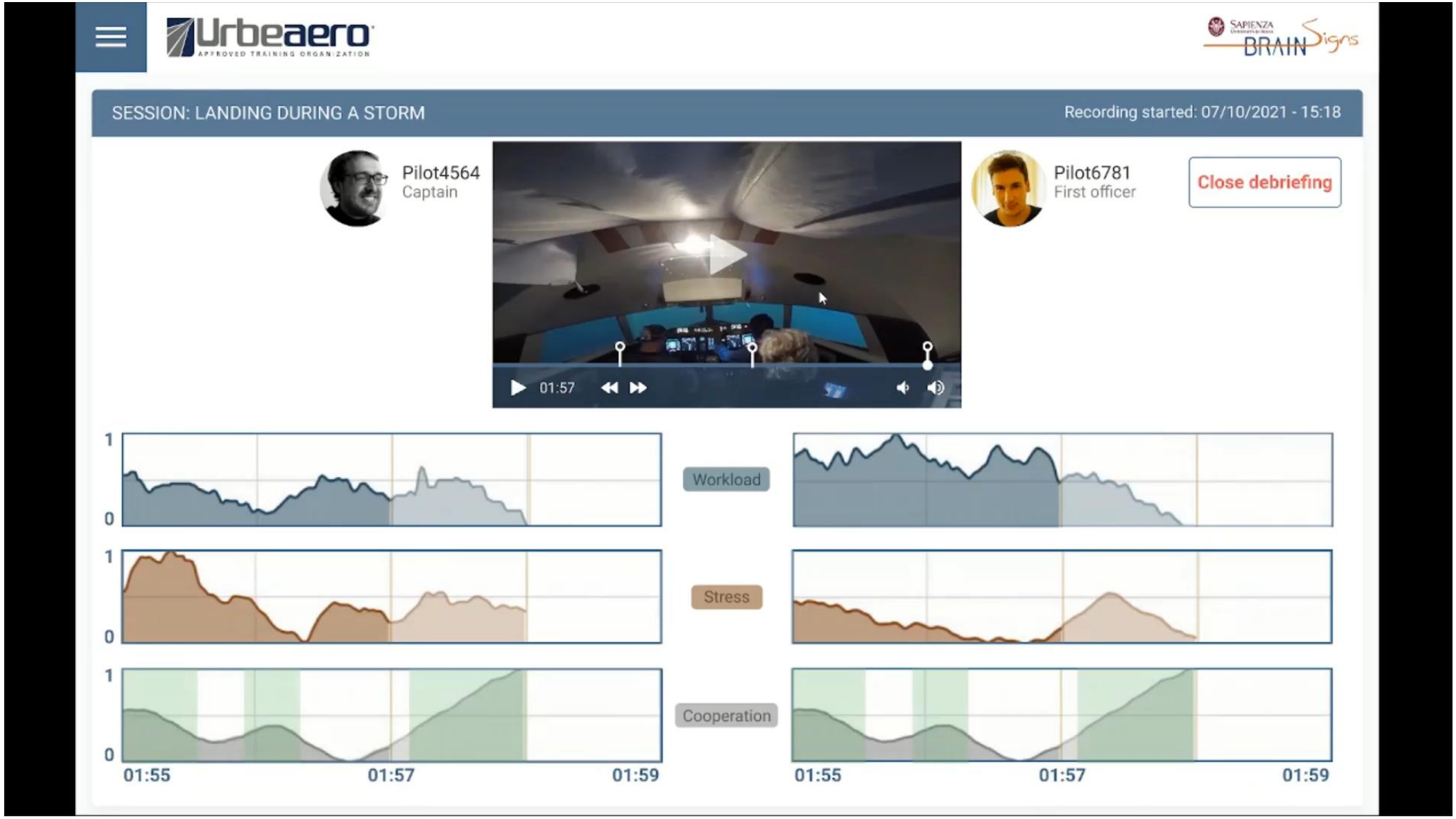
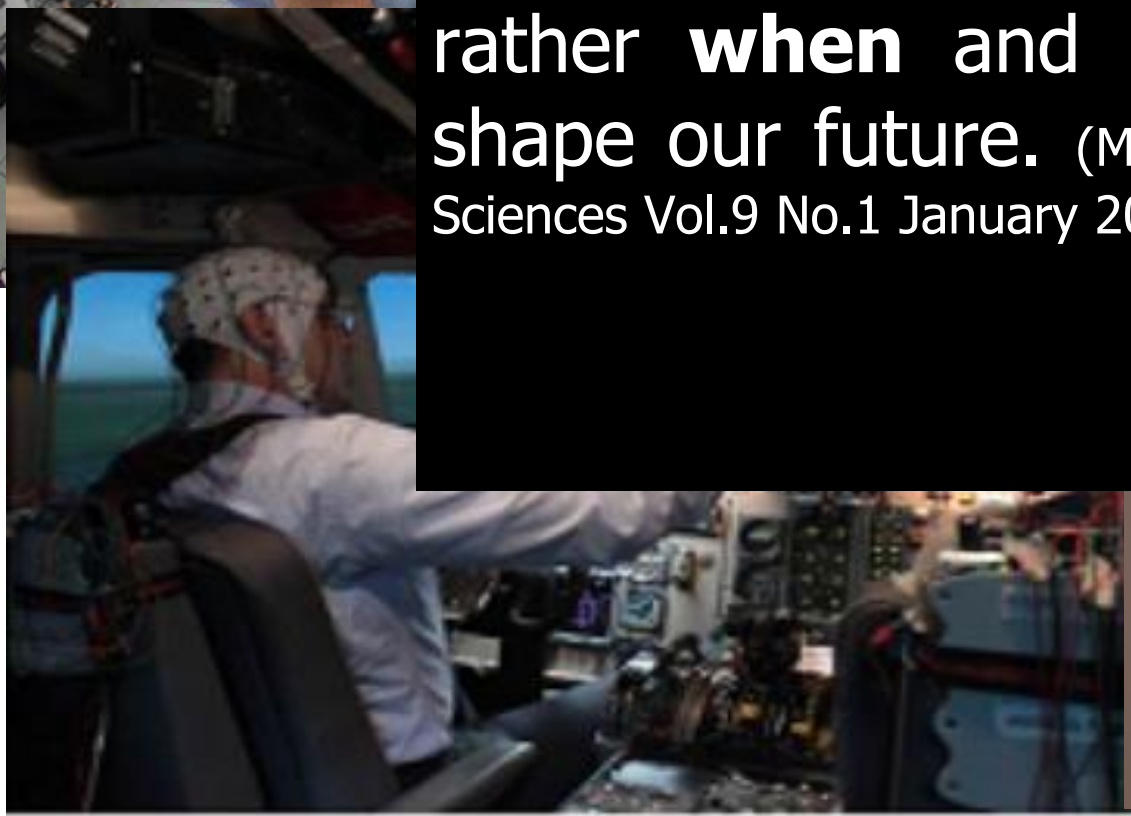
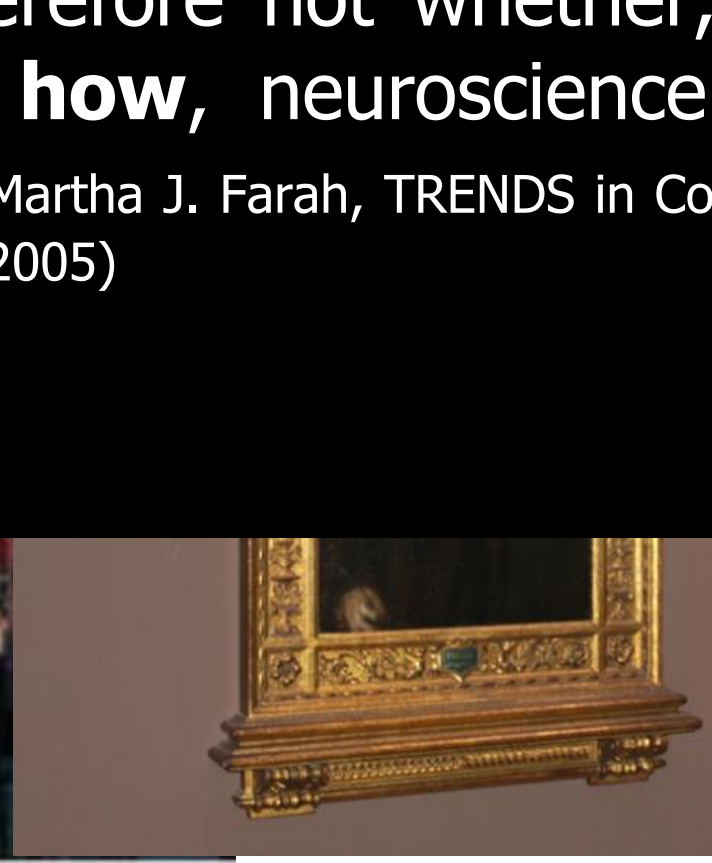
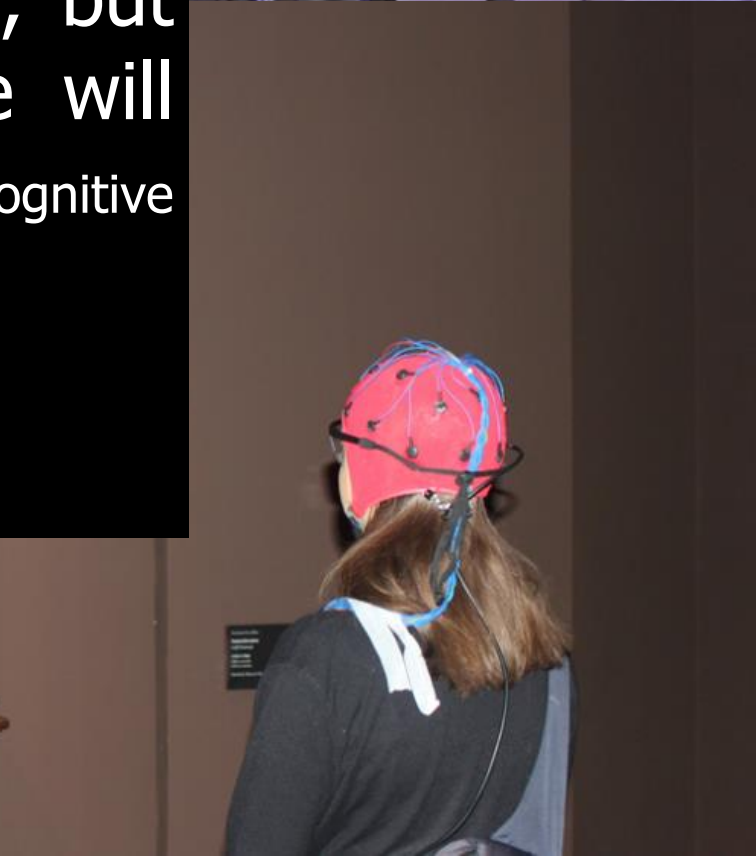
Cooperation estimation: a use case during a simulated emergency landing



The question is therefore not whether, but rather **when** and **how**, neuroscience will shape our future. (Martha J. Farah, TRENDS in Cognitive Sciences Vol.9 No.1 January 2005)







Thank you for your attention!

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