

Skill, Rule and Knowledge based behaviors detection during realistic ATM simulations by means of ATCOs' brain activity

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The NINA Project

NINA – Neurometrics Indicators for ATM

Co-funded by SESAR JU under the Long-term research WP E

Duration:

27 months, from September 2013 to November 2015

Partners:

Deep Blue [coordinator]

Sapienza University of Rome

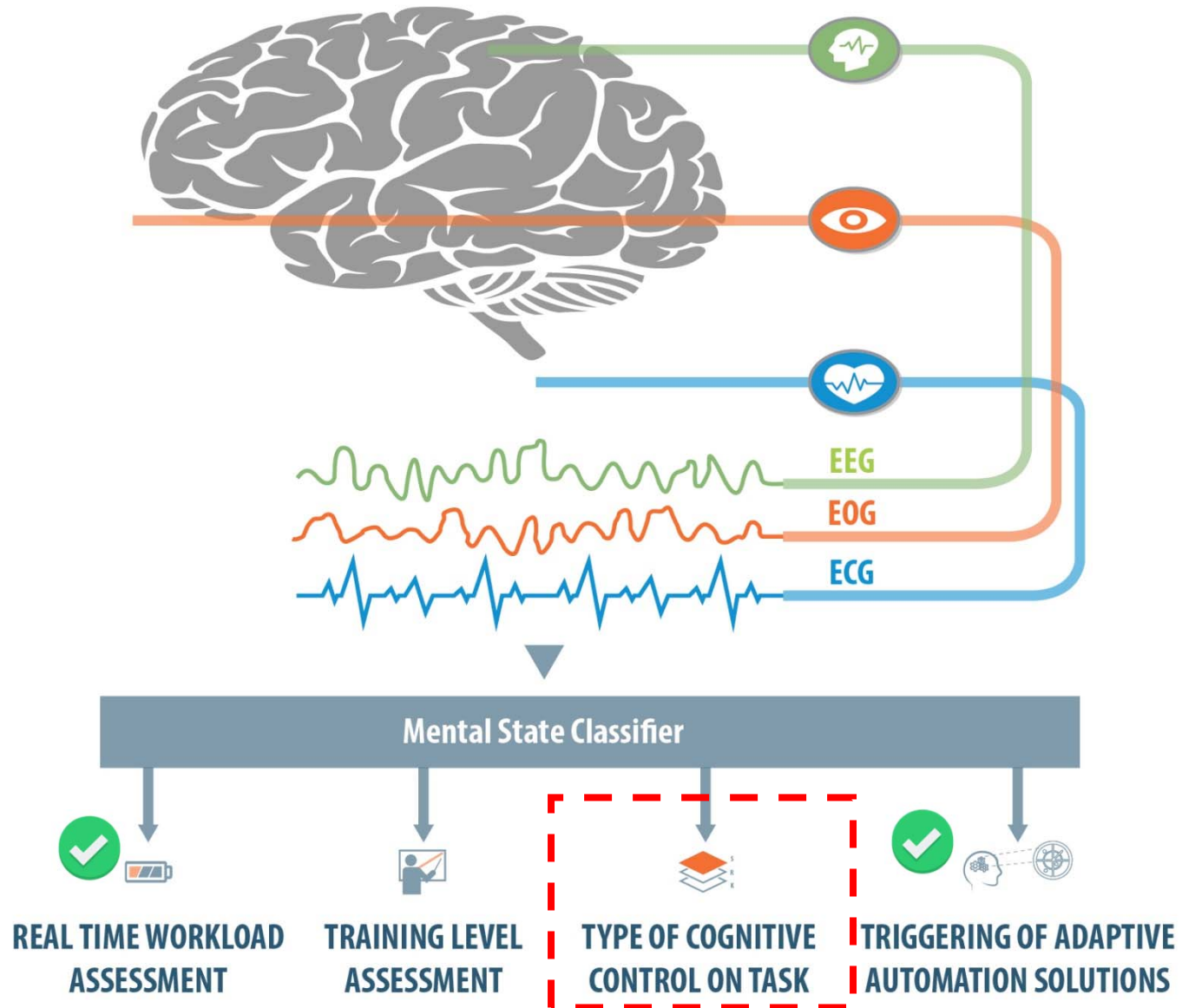
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Context of the study



1. Aim of the study

2. Neurometrics definition

3. SRK events definition

4. Experimental setup

5. Results

6. Future steps

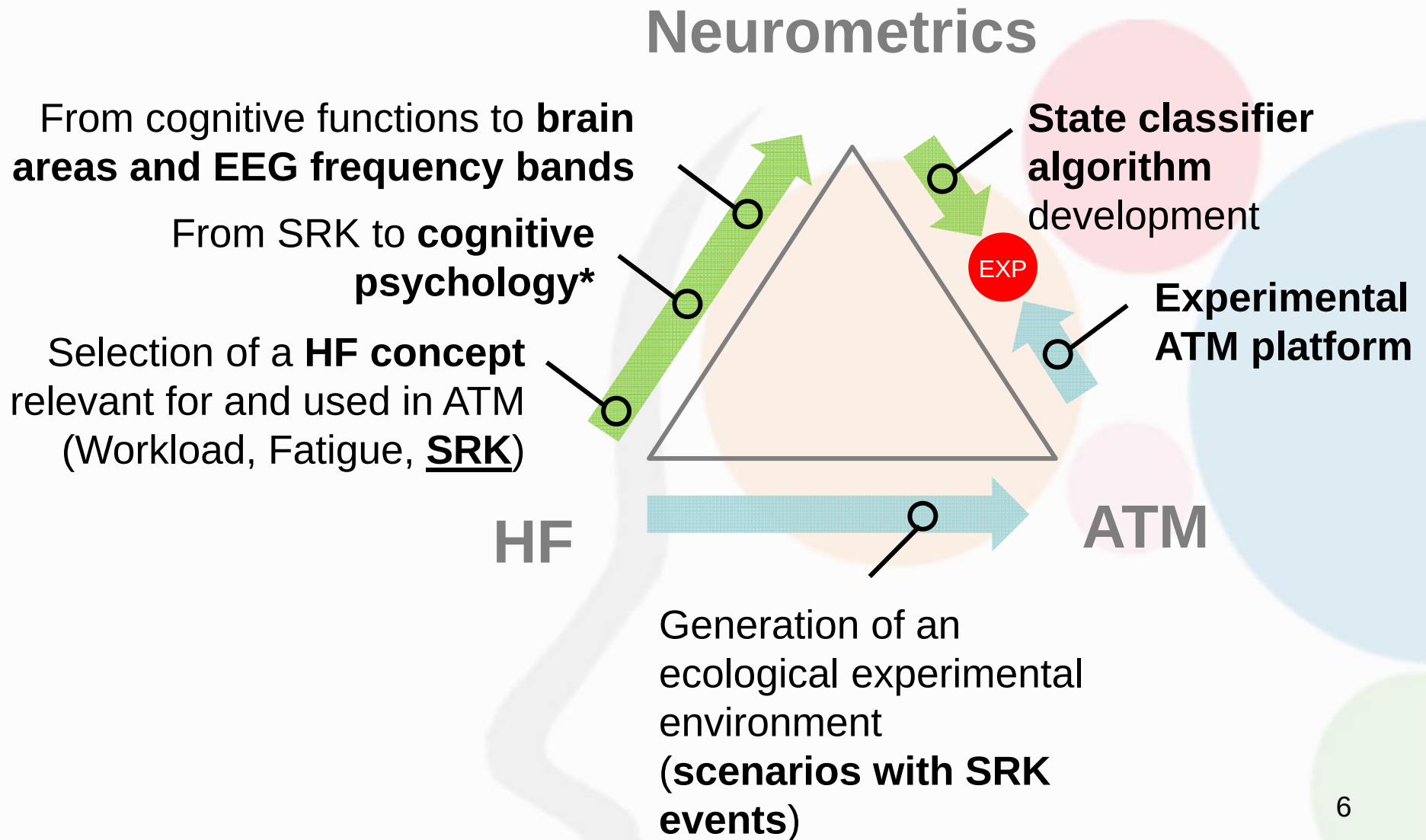
Aim of the study

- To investigate if it was possible to monitor the controllers' **type of cognitive control** exhibited during the execution of realistic **ATM tasks** using **neurophysiological variables**

EXPLORATORY STUDY

- Realistic ATM environment
- Medium sample of subjects (ATCOs)
 - Off line assessment

Phases of the study



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SRK as an ATM relevant HF concept

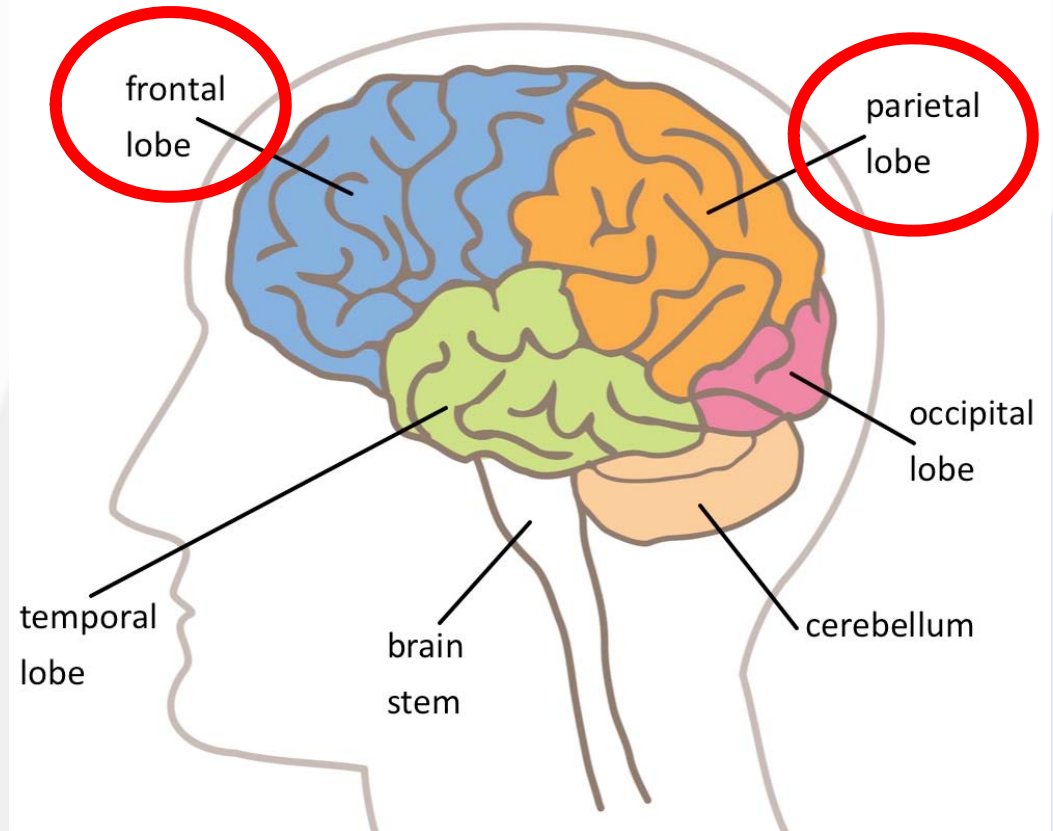
- “**Skill-based** behavior represents sensorimotor performance during acts or activities that, after a statement of an intention, take place without conscious control as smooth, automated, and highly integrated patterns of behavior”
- “At the next level of **rule-based behavior**, the composition of such a sequence of subroutines in a familiar work situation is typically consciously controlled by a stored rule or procedure”
- “During unfamiliar situations, [...] performance is goal-controlled, and **knowledge-based**. The goal is explicitly formulated, then, a useful plan is developed-by selection, such that different plans are considered and their effect tested against the goal. At this level of functional reasoning, the internal structure of the system is explicitly represented by a “mental model”

[J. Rasmussen, 1986, Information Processing and Human-Machine Interaction]

Match among S,R,K based behaviours and cognitive functions

- **Problem setting/solving**
- **Executive control**
- **Attention**
- **Memory** (working/long term)
- **Information processing**
- **Decision making**
- ...

- Decision making, performance monitoring, attention level and difficulty of the executed task
→ Correlation with **prefrontal**, **frontal** and **parietal** brain areas.
- In particular, it has been demonstrated that
 - the **theta** (4-8 [Hz])
 - and **alpha** (8-12 [Hz])
 EEG rhythms, estimated over the considered brain areas, modulate along with the previous processes



Is it possible to use such frequency bands and brain areas to define a neurometric able to discriminate the S-R-K based behaviors?

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SRK in ATM

- Creation: HF expert + Expert ATCO
- Validation: 2 other Expert ATCOs

Skill events were basic interactions with the interface* and the ATCO could be almost entirely focused on them
(S)

The **Rule events** were control and conflicts resolutions tasks, during which controllers were also performing at a skill level
(S+R).

The **Knowledge events** involved the three levels: Skill + Rule + Knowledge.

Events triggering a uncertainty state in controllers, situations that were peculiar enough to make controllers focus on them to try to reduce them to a familiar situation.

After this initial "what is going on?" state, controllers usually came back to the rule level.

(S+R+K).

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Experimental Setup



 ATC Experts: 15
 ATC Students: 22

 Human Factors Experts: 2
 SME (Expert ATCOs): 2

 Pseudo Pilots: 2

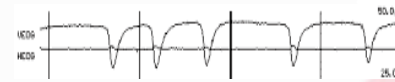
- Duration: 45 minutes
- 6 S-R-K events
- 15 EEG-channels continuous recording



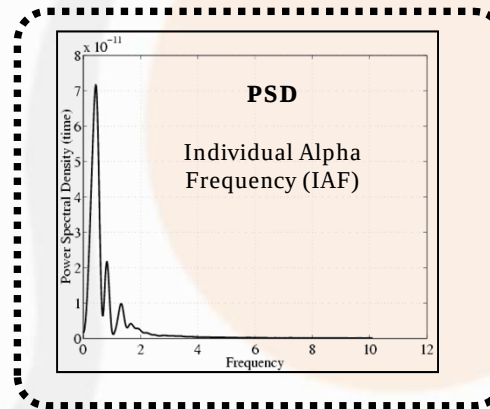
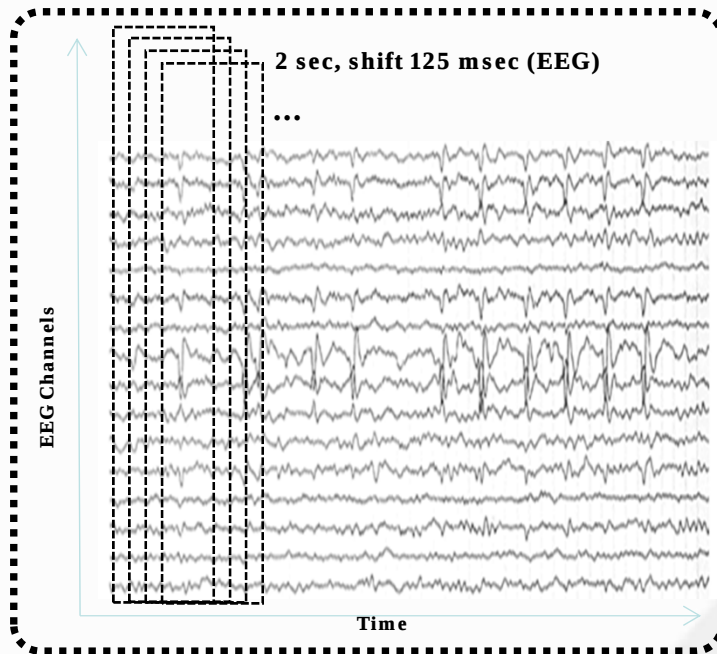
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EEG data analysis

- Ocular regression;
- Threshold criteria;
- Trend estimation;
- Sample-to-sample difference

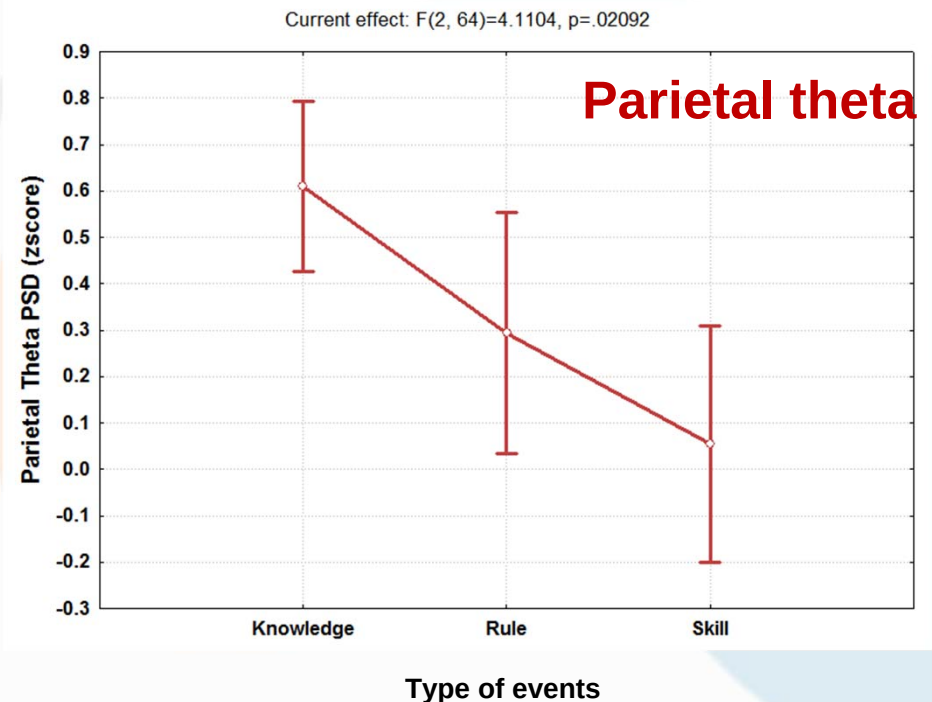
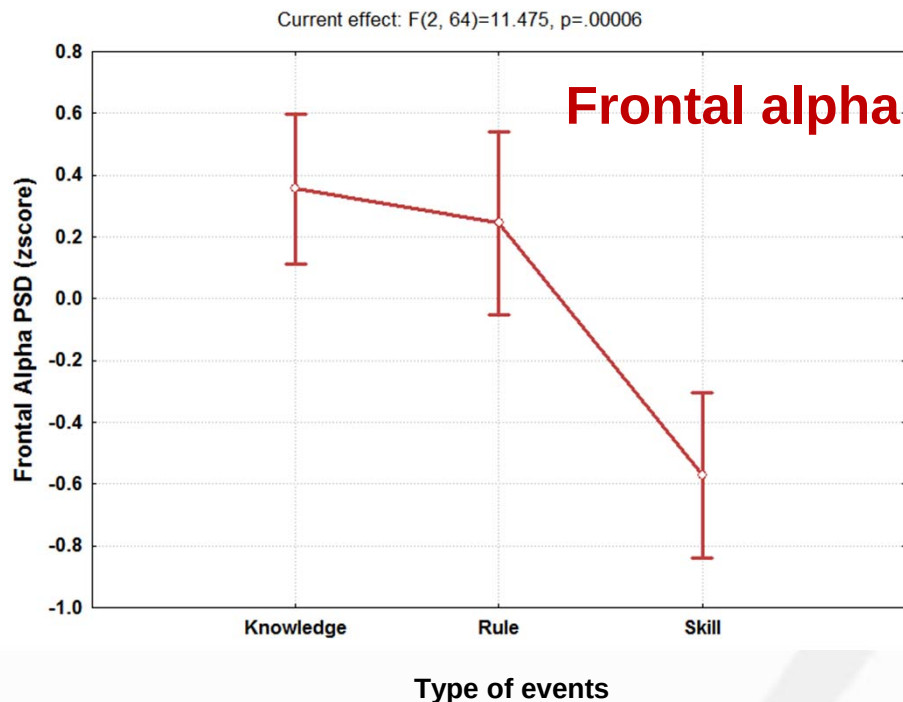


Online Artifacts Correction



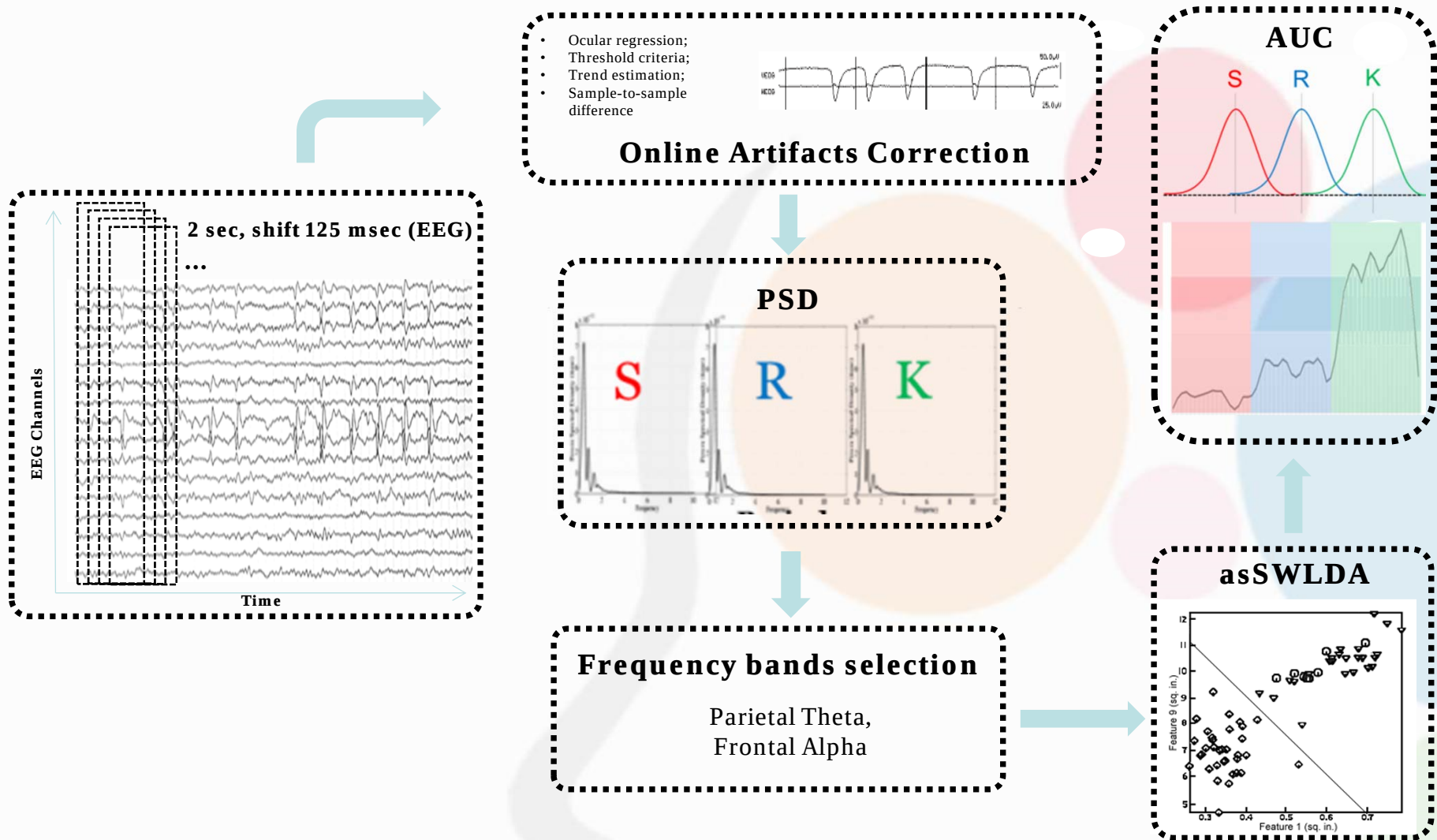
Statistical Analysis

- ❑ **Parietal theta:** memory consolidation and retrieval.
- ❑ **Frontal alpha:** attentional level.

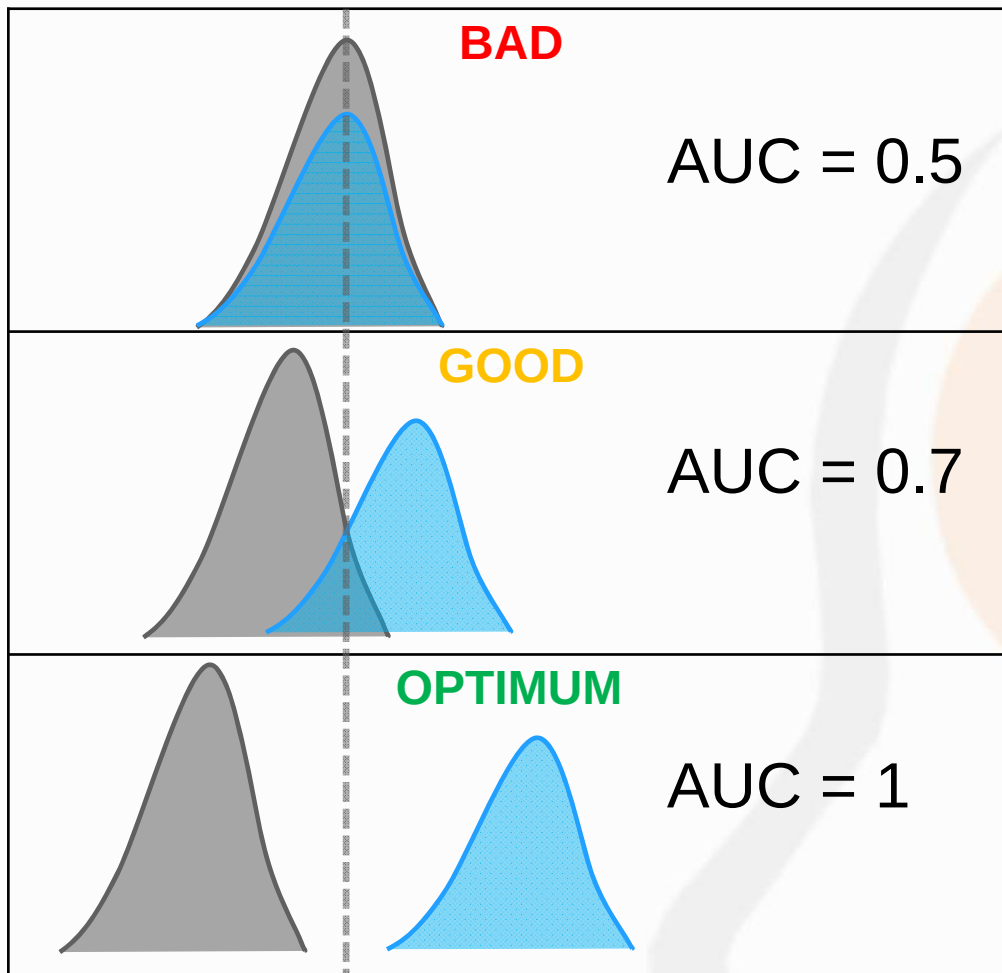


- The **parietal theta** and **frontal alpha**: reliable metric for the **S-R-K discrimination**, since they showed significant different values among the S-R-K conditions (respectively, $p=0.02$ and $p<10^{-4}$).

S-R-K: machine-learning scheme

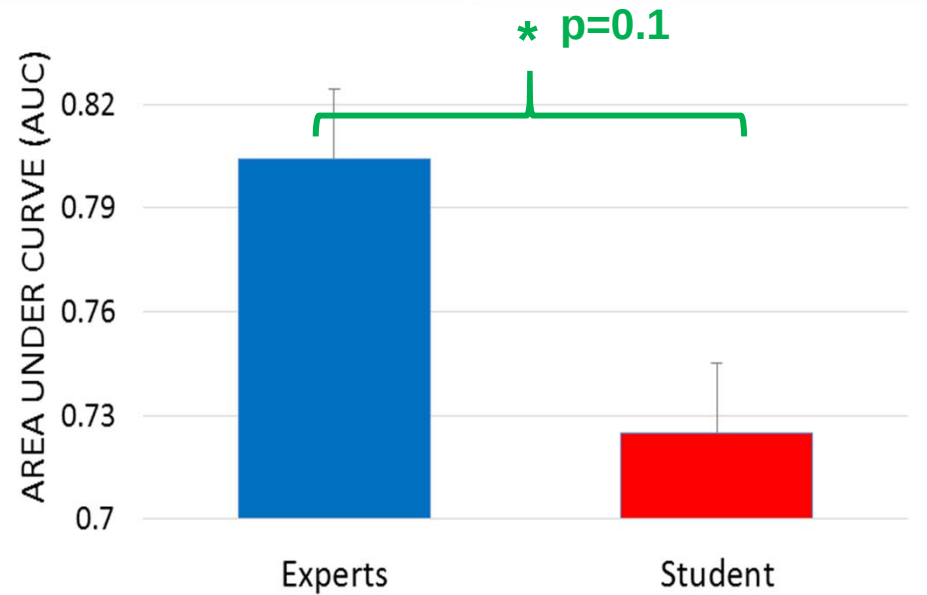
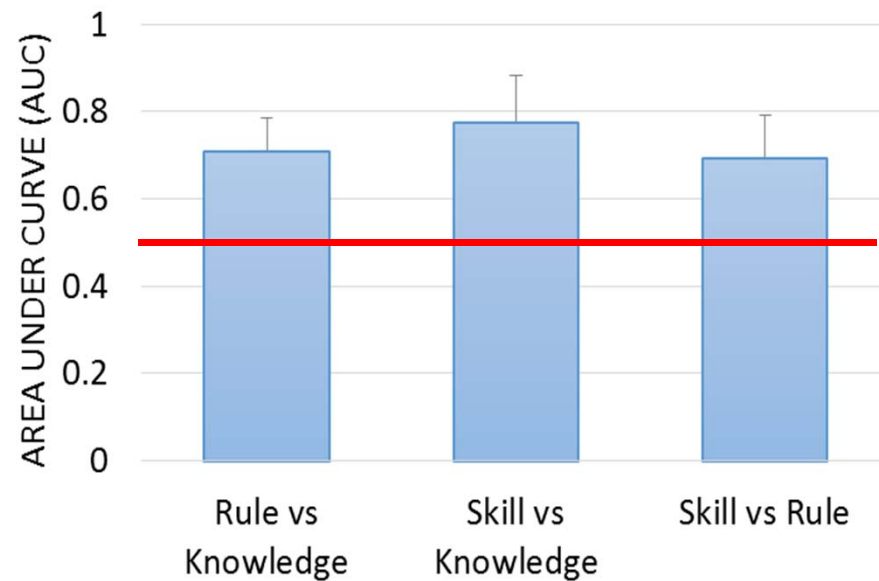


Area Under Curve (AUC)



Parameter to **quantify the discriminability** between data distributions (e.g. S vs R , S vs K , R vs K).

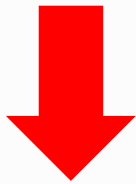
In other words, the quality of the state classifier.



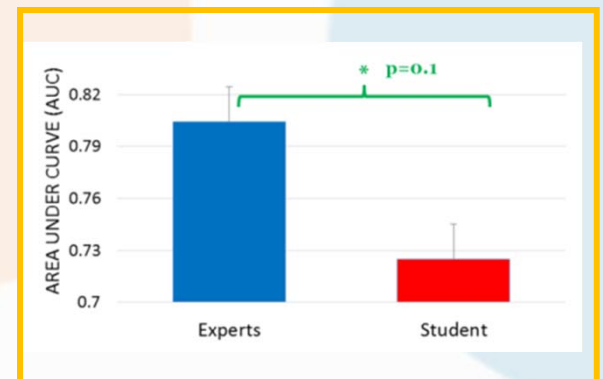
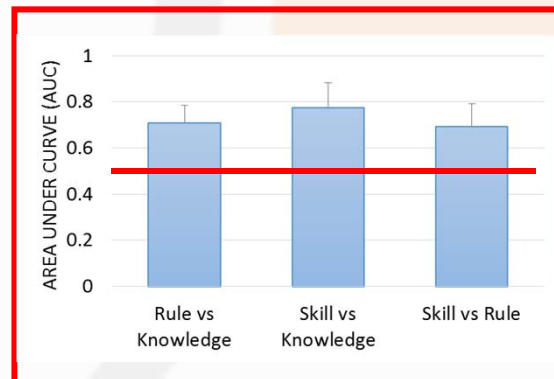
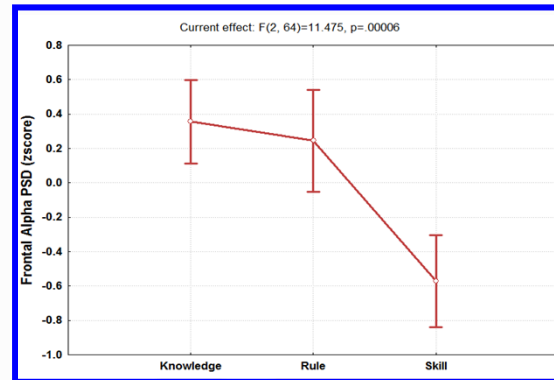
- The t-tests showed that all the measured AUC distributions **were significantly higher with respect** to the random discrimination (AUC=0.5), respectively, all $p < 10^{-8}$ for the *E_ATCO*, and all $p < 10^{-13}$ for the *S_ATCO*.

CONCLUSIONS

Definition of a neurometric
able to discriminate the
S-R-K events.



Methodology able to
assess the **Expertise** of
the User in real
operative
environments.



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- ❑ Better investigate the results in controlled-like experimental setting. Define more appropriate S-R-K events to test the proposed neurometric on SRK “pure” events (decreasing realism).
- ❑ Extend the NINA approach to other HF concepts (STRESS and MOTO projects 2016-2018)

THANK YOU



More information available at:
www.nina-wpe.eu

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