EEG-BCI STRESS MONITORING FOR SAFETY AT WORK

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Nicolai Wolpert

NICOLAI WOLPERT received the master's degree in Cognitive Science from the Ecole Normale Supérieure in Paris, France in 2017, and the Ph.D. degree in Cognitive Neuroscience from the Ecole Normale Supérieure in 2021. His work was centered on the interaction of neural and visceral signals and their role in visual perception. Since September 2021 he is working at Capgemini Engineering in the team of Mind&Act, with a focus on the development of Brain-Computer Interfaces (BCIs) for the monitoring of vigilance and stress.

MIND & ACT: PROJET & AMBITIONS

- Mind & Act is an ambitious multidisciplinary project at the level of the Capgemini Engineering group, aligned with the future challenges of Industry 4.0 and health.

- It aims to develop and test multimodal, non-invasive, mobile, intelligent and interactive BCIs solutions, adaptable in different industrial or clinical contexts.

PROBLEM

- Operators on electricity network exposed to difficult environment and potentially dangerous situations

→ **BCI system to prevent accidents**

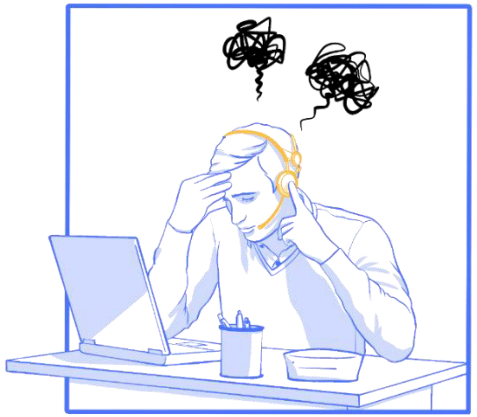
Added values:

- Warning in real time
- Reduction of dangerous situations
- Better care in case of problems
- Help with stress monitoring/decision making

TWO PROFILES

Operations coordinator:

- Main problems : stress, cognitive charge, treatment of information from multiple sources and modalities
- **Target application : monitoring of stress / cognitive charge**



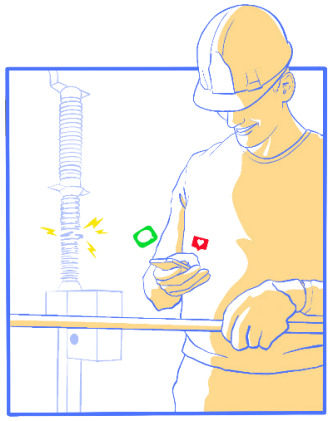
Jerome is an operations coordinator at a company managing electricity networks.

He frequently makes 100+ phone calls (each on a different subject) and works late nights due to high work pressure.

Focus of current project

Technician:

- Main problems : fatigue, drops in vigilance, «tunnel vision», multi-tasking
- **Target application: monitoring of vigilance / selective attention**



Risky errors can be caused by inattention…

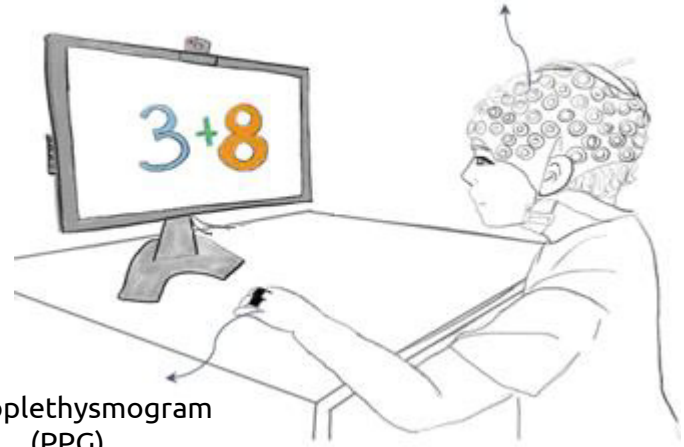
… or due to cognitive load.

Goals

- Develop **task in laboratory** mimicking workers' conditions
  - Pilot task: classic *N*-back task with math equations
  - Multimodal task: auditory N-back + visual working memory items
- Identify **physiological markers** distinguishing different levels of stress and mental workload
- Develop BCI classifiers for the **online detection** of stress
- Adapt BCI solution to the worker's **environment**

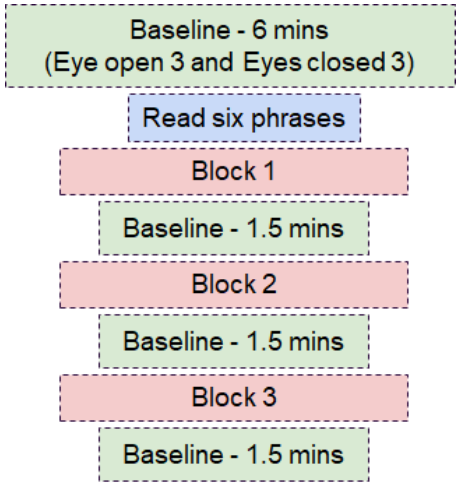
Experiments and protocols – PILOT TASK

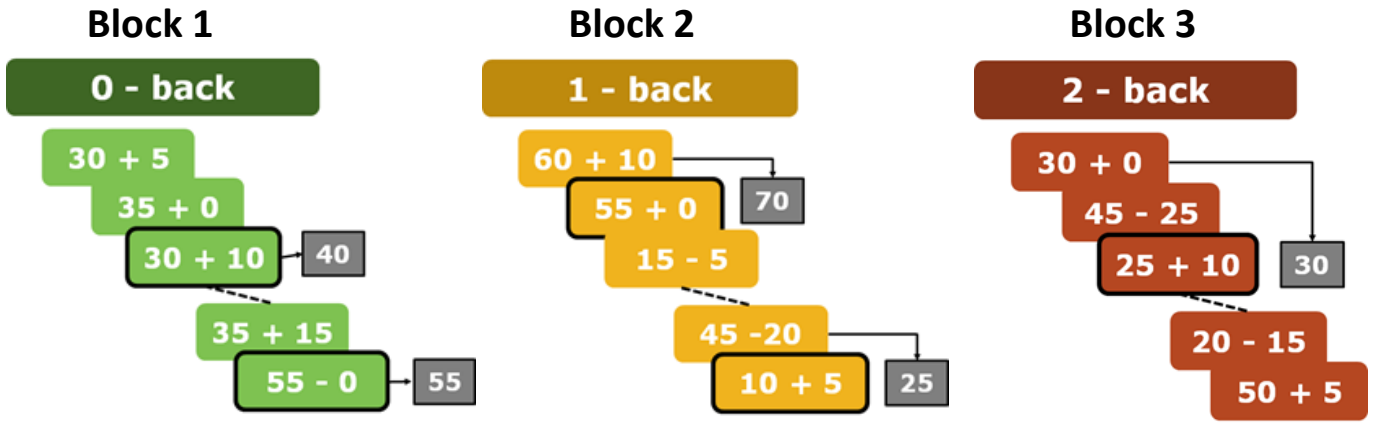
Electroencephalogram (EEG)



Photoplethysmogram (PPG)

19 participants





- Subjects need to solve math equations and memorize the solutions
- At random moments (cued by black square around operation): indicate solution to the *N*-previous equation

→ increasing difficulty/stress with block (0- back to 2-back)

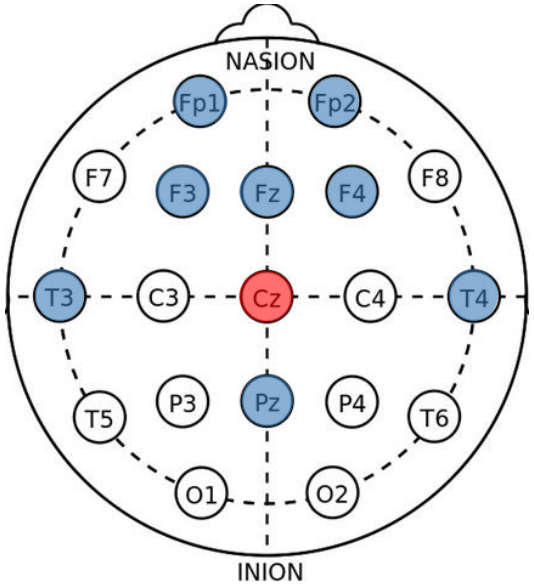
<u>Hypotheses</u>:

With blocks/increase in load:

- Increase in heart rate
- Decrease in alpha power (Al-Shargie et al. 2016; Grissmann et al. 2017)
- Change in beta power (Al-Shargie et al. 2016, 2017; Chen & Huang et al. 2016; Krause et al. 2010)

Experiments and protocols – PILOT TASK

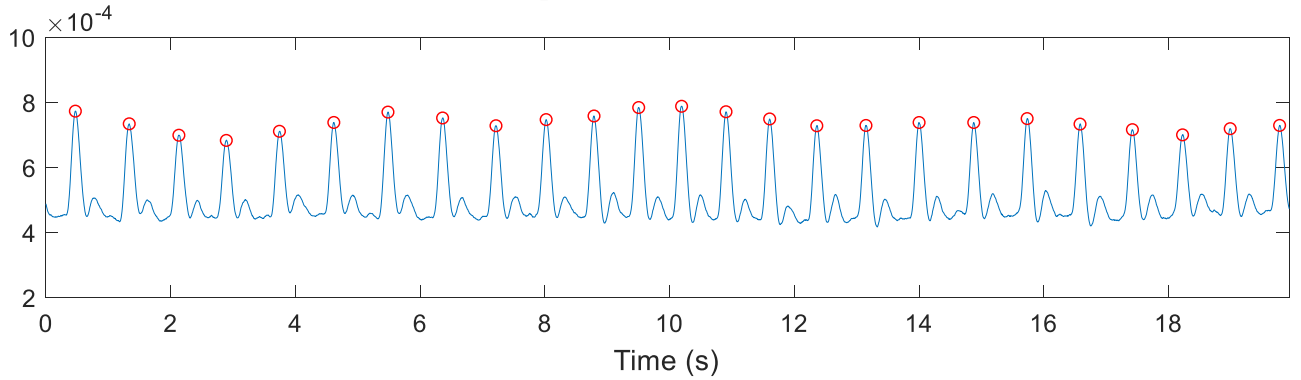
EEG



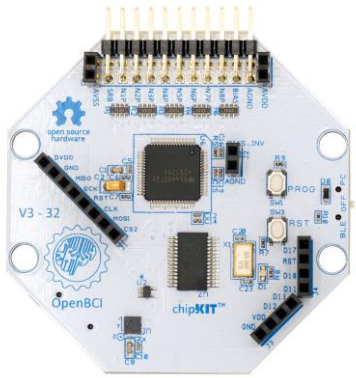
REF = Cz

8 channels (Fp1, Fp2, F3, F4, Fz, T3, T4, Pz)

Photoplethysmogram (PPG)

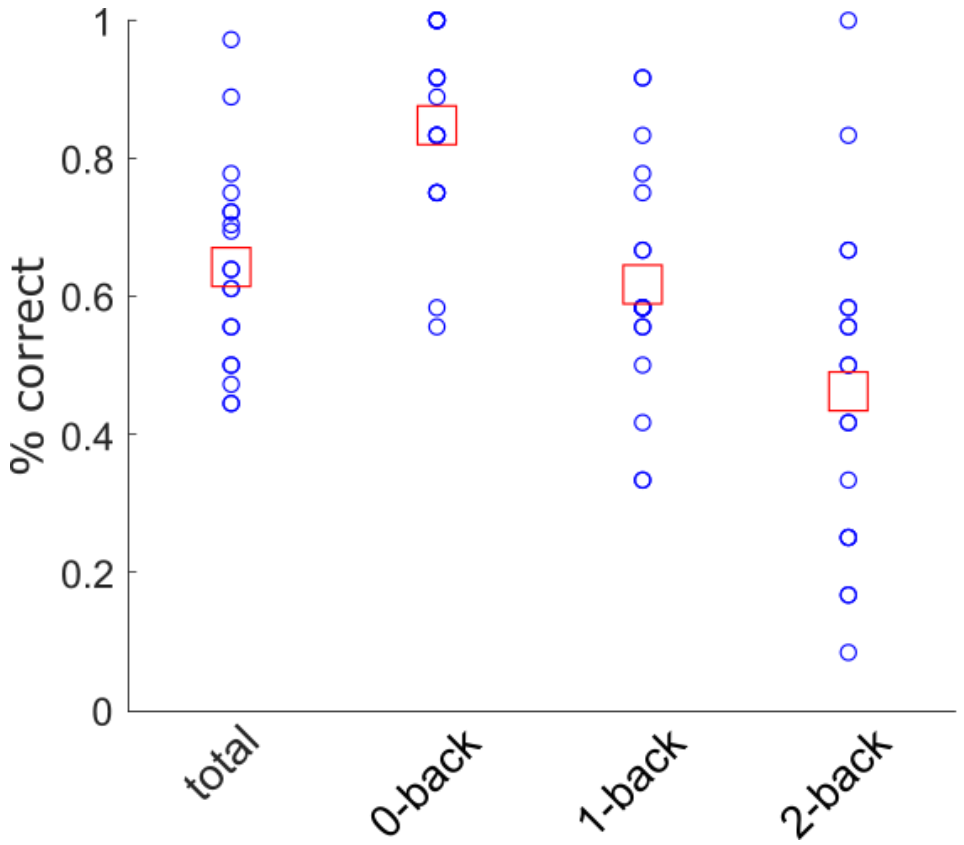


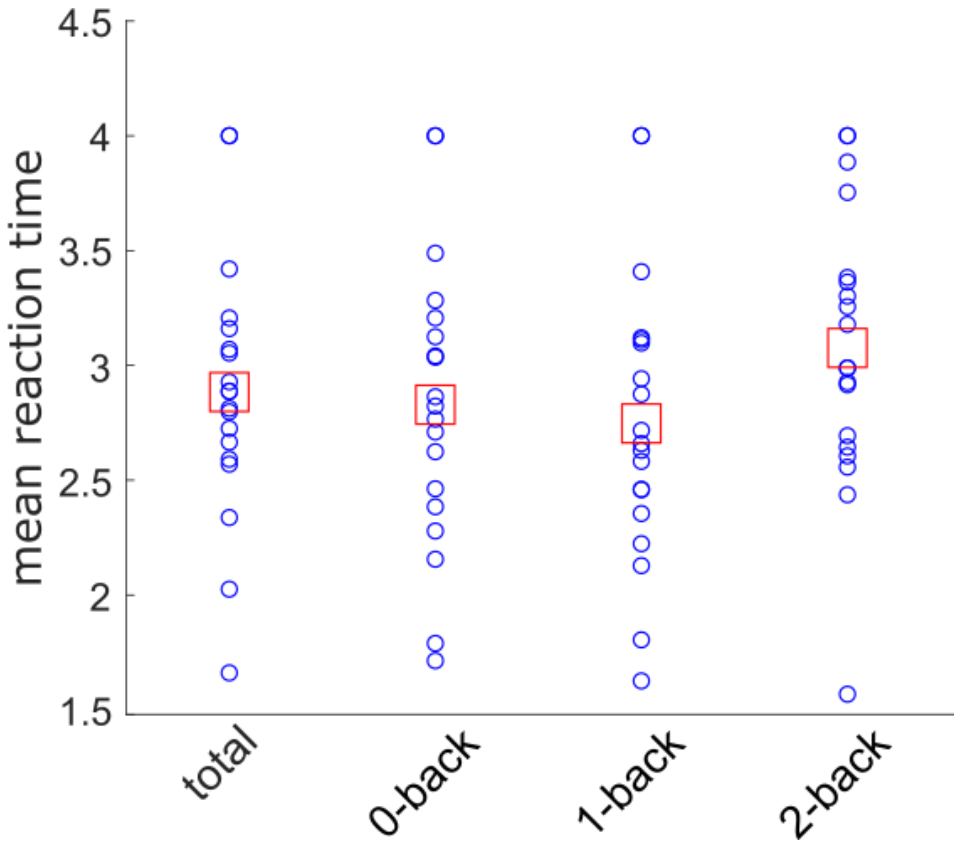
Detect R-peaks to compute heart rate



OpenBCI system

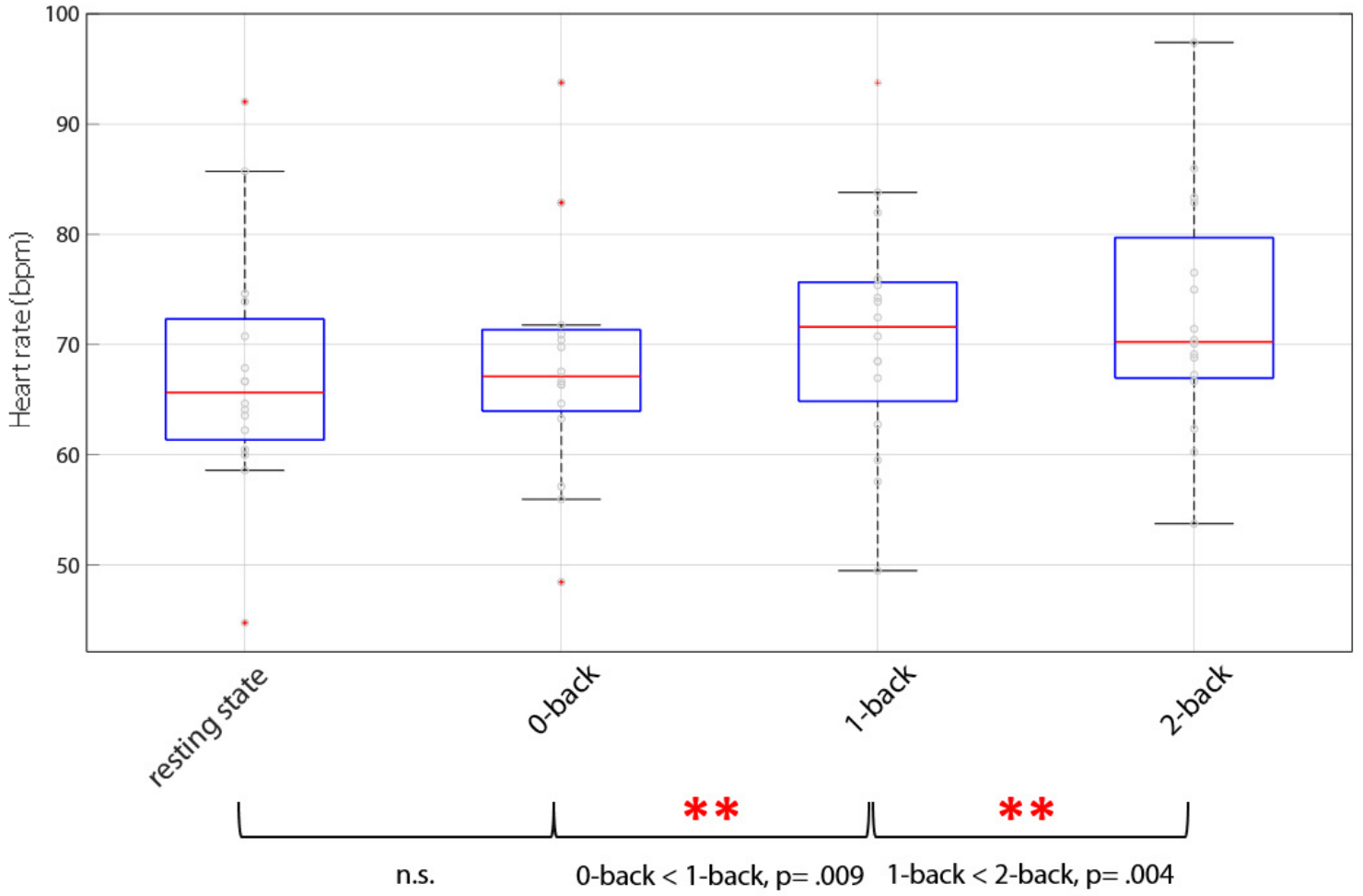
Results PILOT TASK - Behavior





Increasing difficulty visible in %correct responses and reaction time

Results PILOT TASK – Heart rate

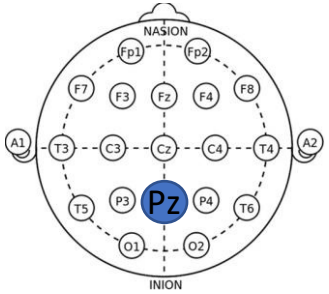


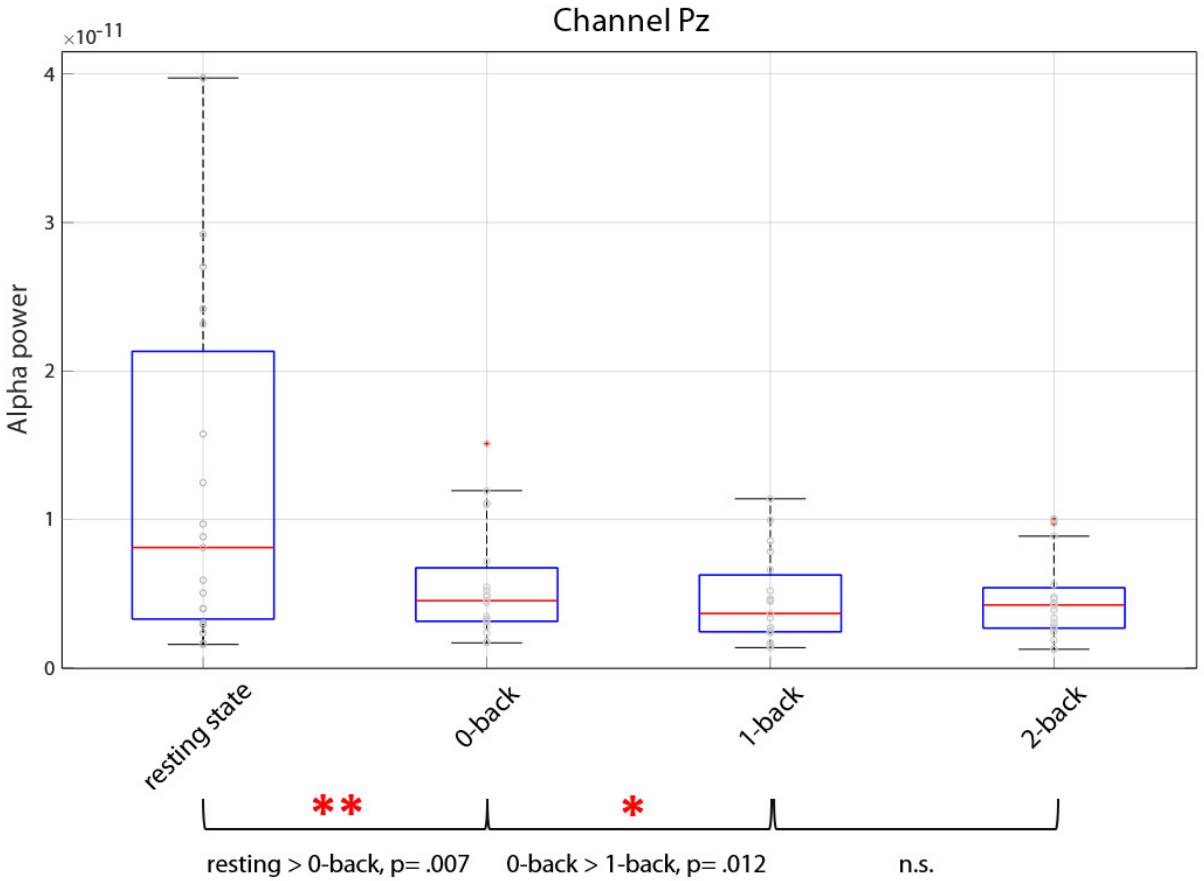
Q3+1.5*(Q3-Q1)
Q1
median
Q3
Q3-1.5*(Q3-Q1)

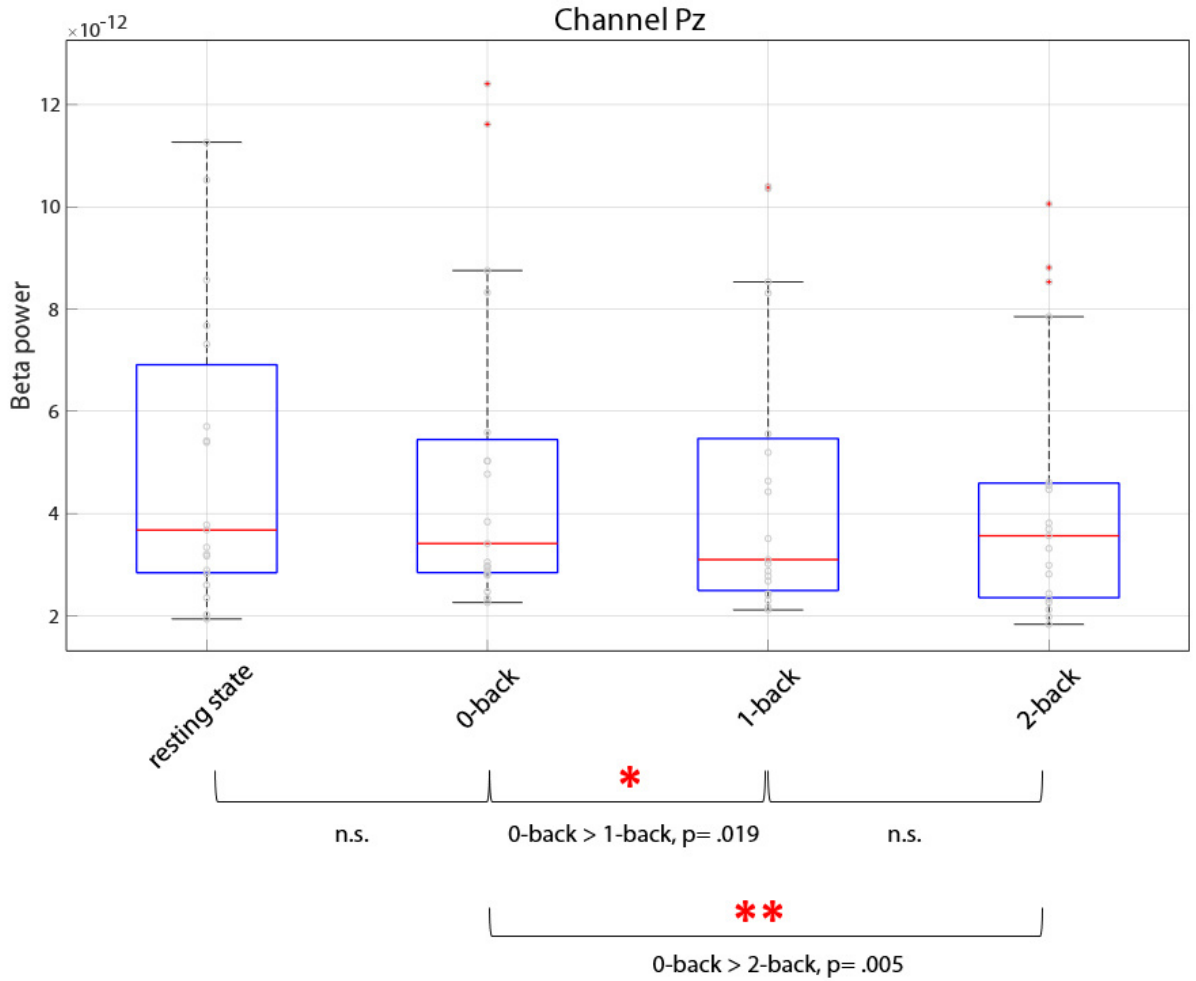
*Paired sample, two-tailed t-test

Increase in heart rate with stress/cognitive charge

Results PILOT TASK – EEG







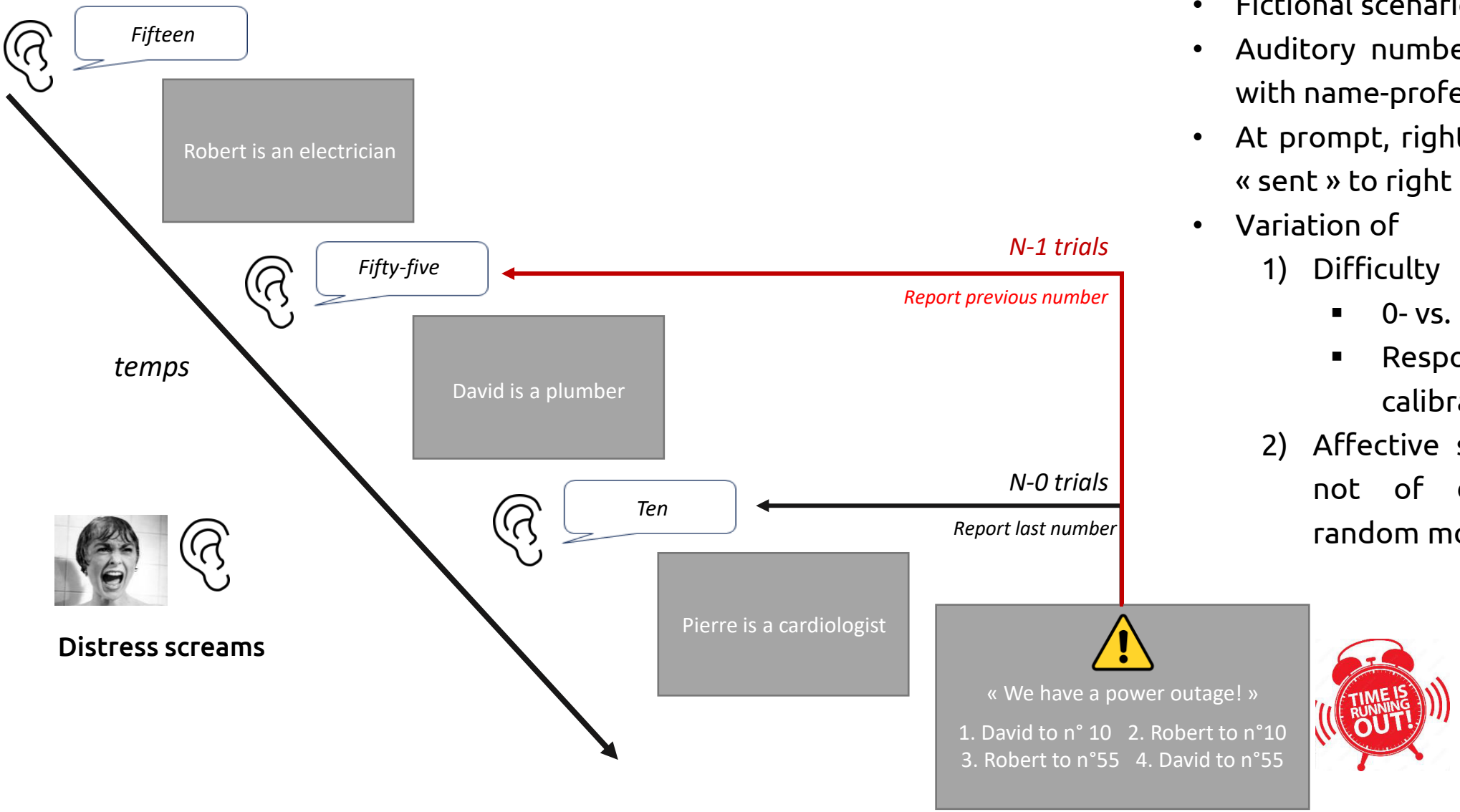
Decrease of alpha and beta with stress/cognitive charge, but no difference between most stressful conditons

Discussion PILOT TASK

- Cognitive load in N-back task linked with (neuro)physiological markers consistent with the literature
  - Increase in heart rate
  - Decrease in EEG alpha power: « De-relaxation » (Al-Shargie et al. 2016, 2017; Grissmann et al. 2017; Lei & Roetting 2011)
  - Decrease in EEG beta power: Desynchronization/decrease with working memory load (Pfurtscheller & Iopez da Silva 1999; Krause et al 2010; for review see Chen & Huang et al. 2016)
- Missing difference between 1- and 2-back block:
  - 2-back might not induce further stress than 1-back
  - 2-back might be too difficult and lead to task-disengagement
- Limitations
  - Large interindividual variability in behavior
  - Not very representative of type of stress workers experience – results generalizable?

Create task more natural / similar to workers' conditions

Experiments and protocols – MULTIMODAL TASK



- Fictional scenario with urgency calls
- Auditory numbers + visual sentences with name-profession associations
- At prompt, right « person » has to be « sent » to right number
- Variation of
  1) Difficulty
     - 0- vs. 1-back trials
     - Response time limit, calibrated online
  2) Affective stress by inclusion or not of distress screams at random moments

Conclusion

Next steps

- Refinement of multimodal task and data acquisition
- Identification of markers of stress/cognitive charge
- Development of (online) classification algorithms for stress and cognitive charge

Perspectives

- Project is above all investigation how neuroscience can support **better understanding of human factor**
- If successful for this specific use case, might be **applied to other situations** in future