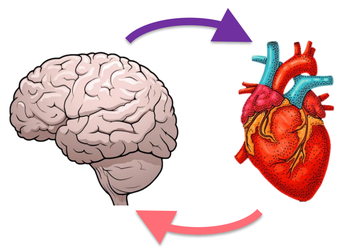
Linking emotional arousal to the heartbeat-evoked potential in immersive virtual reality



Fourcade A.[1,2,3,4]*, Klotzsche, F.[2,3], Hofmann, S. M.[2,5], Mariola, A.[6,7], Villringer A.[1,2,3,4] and Gaebler M.[2,3]

[1]Max Planck School of Cognition, Leipzig, Germany
[2]Department of Neurology, Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany
[3]Humboldt-Universität zu Berlin, Faculty of Philosophy, Berlin School of Mind and Brain, MindBrainBody Institute
[4]Charité - Universitätsmedizin Berlin, Germany
[5]Department of Artificial Intelligence, Fraunhofer Institute Heinrich-Hertz, Berlin, Germany
[6]Sussex Neuroscience, School of Life Sciences,University of Sussex, Brighton, UK
[7]Sackler Centre for Consciousness Science, School of Informatics, University of Sussex, Brighton, UK

antonin.fourcade@maxplanckschools.de

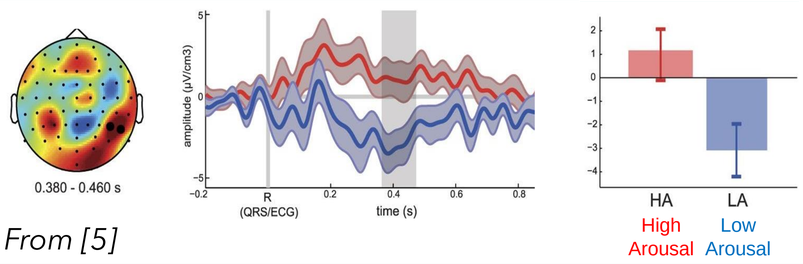
Mind Brain Body Institute

MAX PLANCK SCHOOL of cognition

MAX PLANCK INSTITUTE FOR HUMAN COGNITIVE AND BRAIN SCIENCES

Introduction

- Bodily (e.g., visceral) signals are constantly processed by brain, influencing perception, action, and subjective experience.
- Heartbeat-evoked potential (HEP): cortical processing of heartbeat [1]; associated with cognitive and emotional processes [2]
- Emotional arousal: core dimension of emotional experience [3]
- Immersive virtual reality (VR) enables naturalistic (i.e., dynamic, interactive) experiments [4]

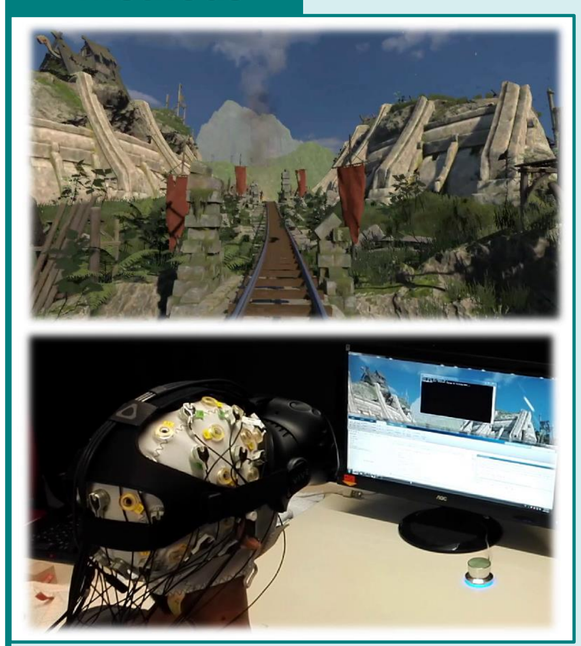


From [5]

HEP differences between high arousal (HA) and low arousal (LA) under naturalistic stimulation?

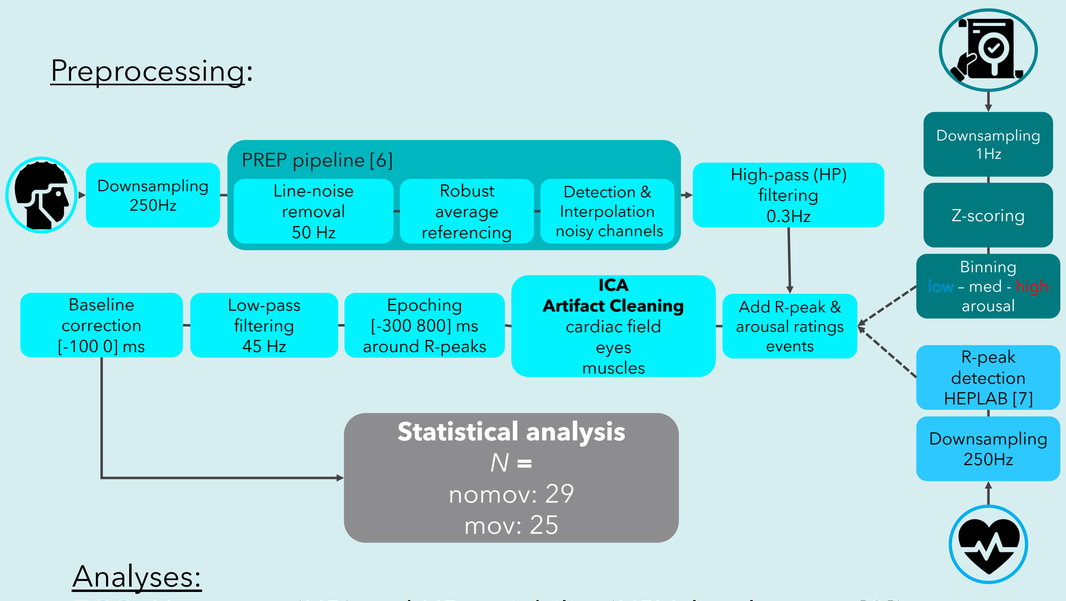
Hypothesis (from [5]): HEP amplitude: HA > LA
- Time window after R-peak: 250 to 500 ms
- Location: temporo-parietal electrodes

Methods



Acquisition:
- 37 young, healthy participants
- 30-channel **EEG** & 1-lead **ECG**
- Retrospective **ratings** (replay): Emotional arousal (scale: 1-50)
- 2 (within-subject) head movement conditions: mov & nomov

Preprocessing:



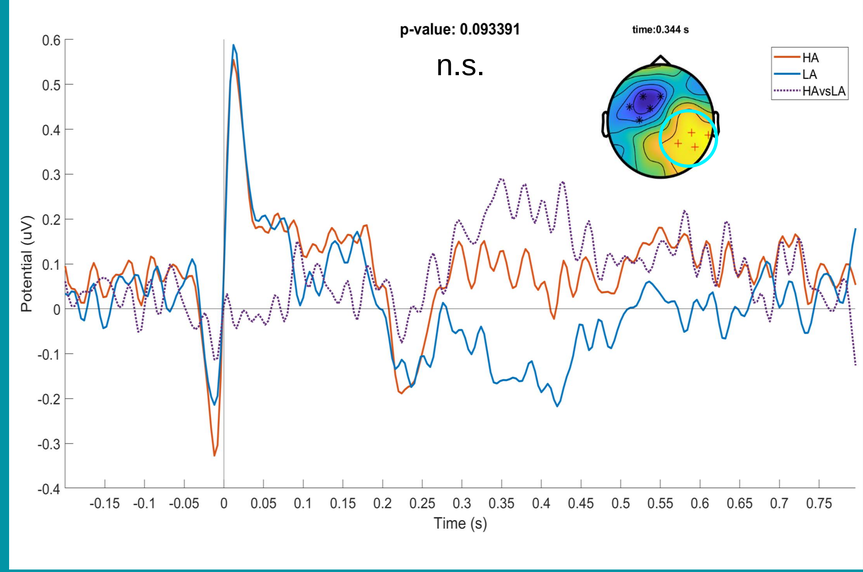
Analyses:

ECG: Heart rate (HR) and HR variability (HRV; local power [8])
→ Linear mixed effects model
- fixed effects: arousal (HA, LA), head movement (mov, nomov)
- random effect: subjects

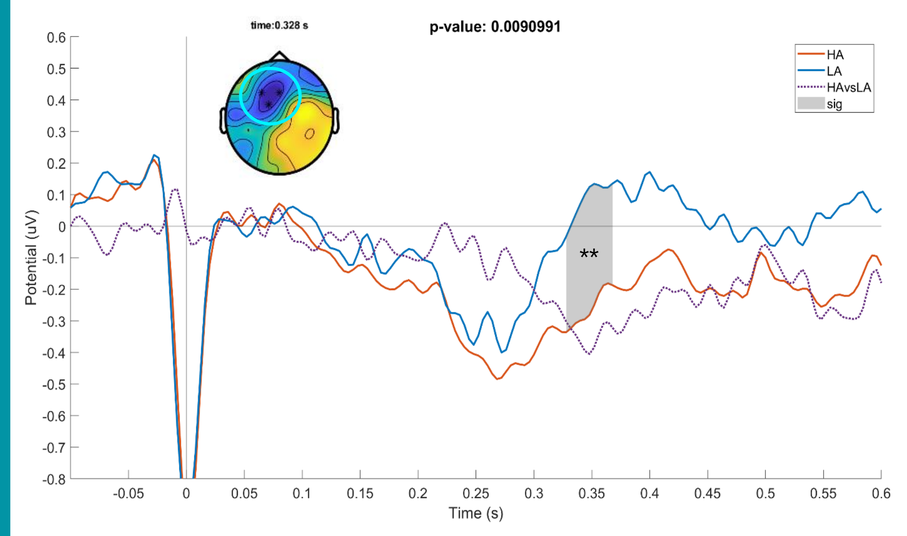
EEG: HEP profiles
→ Non-parametric cluster-based permutation t-tests
- Pooling mov & nomov data.
- Cluster threshold p-value of 0.05
- 10,000 random permutations
- Clusters with $p < .05$ (two-tailed) considered "significant"

Results

1 **No evidence** for HEP amplitude HA > LA

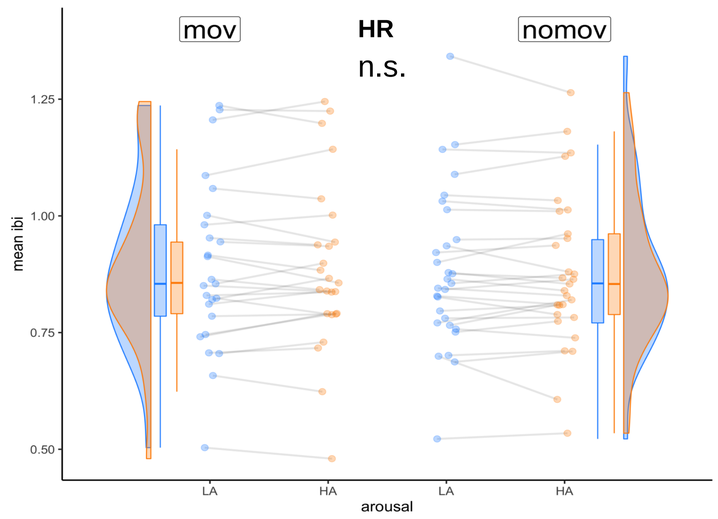


2 **Frontal cluster:**
HEP amplitude **HA < LA** (Monte Carlo $p < .01$)
- 320 to 370 ms after R-peak

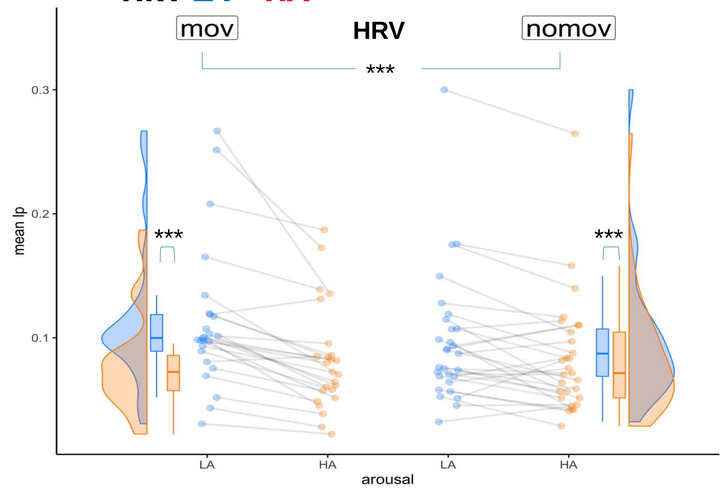


Control Analyses

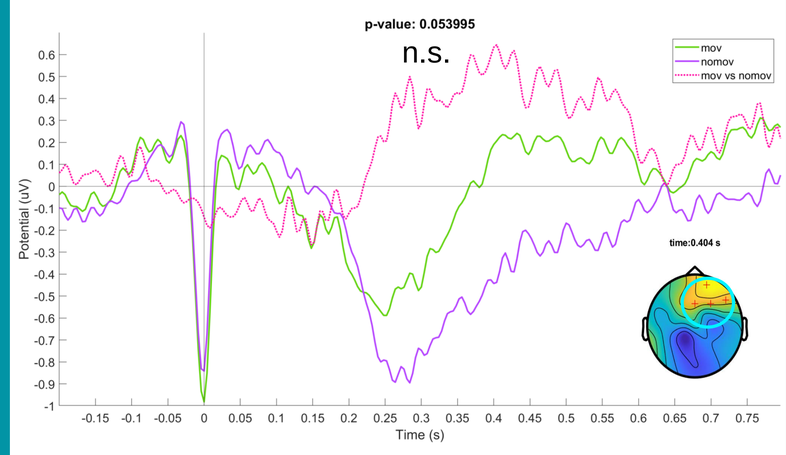
3 HR - No significant effects of arousal, head movement & interaction



4 HRV - Significant effects of arousal ($p < .001$), movement ($p < .001$) & interaction ($p < .001$)
- **HRV LA > HA**



5 No significant differences between mov & nomov



Discussion

- **Summary**: Under naturalistic conditions, (1) no evidence for higher HEP amplitudes during high arousal (HA) than low arousal (LA) over temporo-parietal electrodes; (2) higher HEP amplitude during LA than during HA over left frontal electrodes. Pattern could be due to electrophysiological properties (dipole).
- HEP difference could be related to HRV difference.
- Frontal cortices associated with changes in heart rate [9], heart rate variability [10], and regulation of emotional arousal [11].

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