The influence of cardiorespiratory phase locking and heart-brain interactions on the sense of agency – a project idea

Gerosa, M. [1,2], Haggard, P. [3], Villringer, A. [1,2], & Gaebler, M. [1,2]

[1] Berlin School of Mind and Brain, Faculty of Philosophy, Humboldt-Universität zu Berlin, Berlin;
[2] Department of Neurology, Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig;
[3] Institute of Cognitive Neuroscience, University College London, London.

gerosa@cbs.mpg.de

Deutscher Akademischer Austauschdienst
German Academic Exchange Service

Introduction

- **Sense of agency (SoA)** is the experience of controlling one's own actions and their effects (Haggard, 2017).
- SoA traditionally investigated via the **intentional binding effect** (Haggard et al., 2002; Moore & Obhi, 2012), i.e., the subjective temporal compression between a voluntary action and its sensory outcomes.
- **Voluntary action initiation** found to be **entrained by cardiorespiratory fluctuations**: e.g., increased tendency to initiate motor acts during systole (Kunzendorf et al., 2019) and expiration (Park et al., 2020).
- Cardiorespiratory fluctuations may serve as a **predictable reference frame** in the interactions with the environment (Park & Tallon-Baudry, 2014), thus providing optimal windows for action and perception.
- This may be in turn **beneficial for SoA**, in line with interoceptive predictive coding models of conscious presence and agency (e.g., Marshall et al., 2018; Seth et al., 2012): e.g., higher SoA for freely chosen actions initiated at systole than diastole (Herman & Tsakiris, 2020; Koreki et al., 2022).

Research questions

The aim of my doctoral project is to investigate the **link between cardio-respiratory signalling, voluntary action initiation and SoA**.

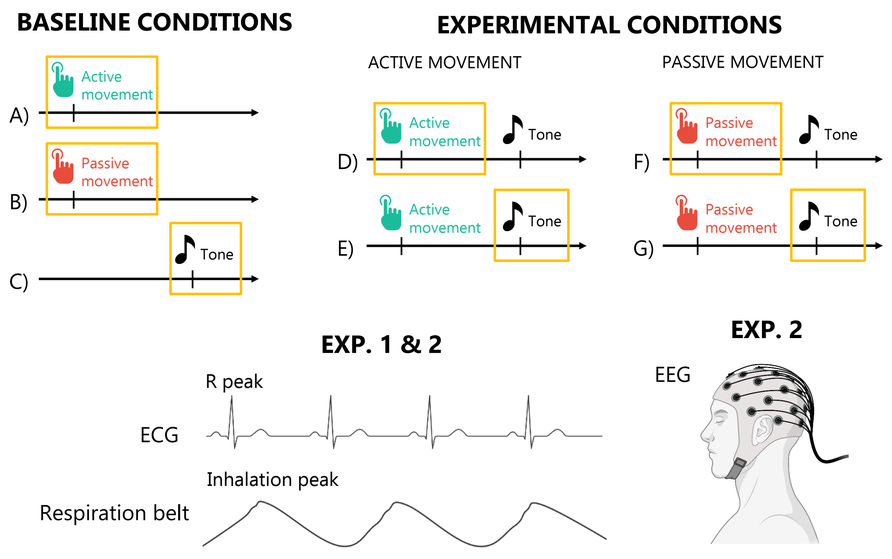
Moreover, the **neurophysiological markers** of such brain-body interactions, namely heartbeat-evoked potentials (HEPs) and sensory attenuation of the auditory-evoked N1 component (as another SoA proxy), will be investigated.

Two complementary experiments:

1. **Exp. 1:** does the phase-locking of voluntary movements, but not involuntary ones, with the cardiorespiratory cycles modulate SoA, indexed by intentional binding measures?
2. **Exp. 2:** does the amplitude of HEPs before voluntary movements differentially modulate SoA?

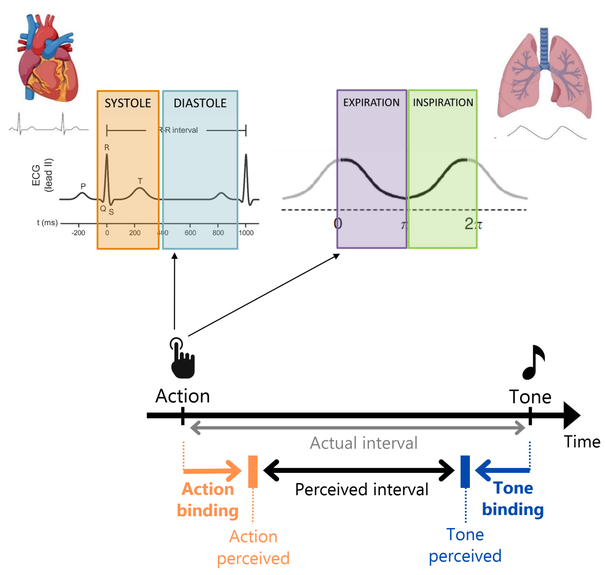
Methods

Intentional binding task



- Libet-inspired clock to report the timing of single events (in yellow);
- **Seven conditions**: 3 baseline conditions, 2 active movement and 2 passive movement experimental conditions;
- Separate blocks of **40 trials** each;
- Possibility of testing **different temporal delays** (e.g., 250, 400 and 700 ms).

Cardio-respiratory data analysis

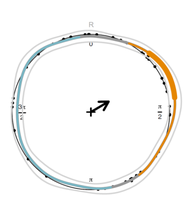


BINARY ANALYSIS

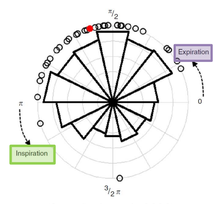
- **Phasic nature** of cardiorespiratory activity
- Cardiac cycle movement onset: SYS vs. DIA
- Respiratory cycle movement onset: EXP vs. INS
- Repeated-measure ANOVAs: 2 (active vs. passive movement) x 2 (SYS vs. DIA) x 2 (INS vs. EXP), with main measures from intentional binding task.

CIRCULAR ANALYSIS

- **Oscillatory nature** of cardiorespiratory activity
- Rayleigh tests (Pewsey et al., 2013) and non-parametric bootstrapping (Kunzendorf et al., 2019) to test the deviation of DVs from a uniform distribution.



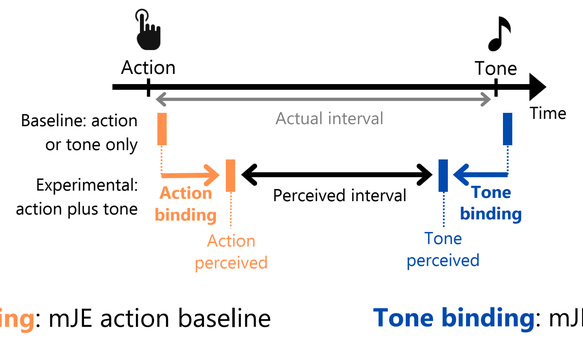
(from Kunzendorf et al., 2019)



(from Park et al., 2020)

Behavioural measures

Mean judgement error (mJE): difference of average perceived and actual times of occurrence of each event.



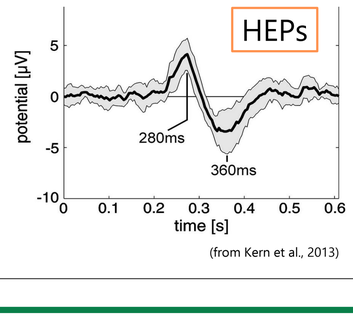
Action binding: mJE action baseline – mJE action experimental conditions

Tone binding: mJE tone baseline – tone experimental condition

Total intentional binding: action binding + tone binding

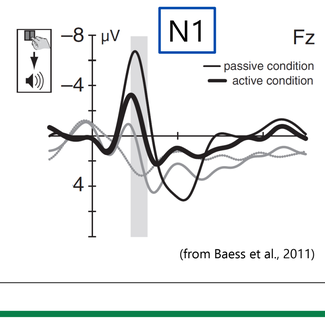
EEG data analysis

- **HEPs** before movement onset in **250-400 ms** time window **after R-peak** (Al et al., 2020).
- Trials sorted in three equal bins of pre-movement HEPs amplitude, then correlated with intentional binding measures.



(from Kern et al., 2013)

- Sensory attenuation of the **auditory-evoked N1 in 140-170ms time window** after tone (van Elk et al., 2014), in tone baseline vs. experimental conditions.
- rm-ANOVA with 2 (active vs. passive movement) x 2 (SYS vs. DIA) x 2 (INS vs. EXP).



(from Baess et al., 2011)

Open questions

- How could **involuntary movements be yoked** to the same cardiorespiratory phases of voluntary movement initiation?
- Could SoA be modulated by whether **action and outcome** fall in **different or similar cardiorespiratory phases** (e.g., SYS-DIA vs. DIA-DIA)?
- Could different durations of **physiological rhythms** influence the **instrumental temporal relation** between action and outcome?
- Could inter-individual differences in **heart or respiration frequency** modulate which action-outcome temporal relation is optimal for SoA?

References

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