RESPIRATION, COGNITION AND THE BRAIN

Workshop

SCHOOL OF COMMUNICATION AND CULTURE
AARHUS UNIVERSITY

LAURA BOCK PAULSEN
PH.D. STUDENT

WHAT WILL WE BE COVERING?

Background

- Respiration

Ongoing study investigating how breathing affects processing of temporally predictive tactile stimulation

- Methods — how to preprocess and analyse respiration data
- Pilot results

Working on respiration and behavioural data from the MEG lab

- *Pyriodic* — python module under development for MSc thesis

WHAT LANGUAGE TELLS US ABOUT BREATHING

Take ones breath away

Catch your breath

Take a deep breath

I need some breathing room

A sigh of relief

Hold your breath

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RESPIRATION

Inspiration

- Muscles contract to expand the thoracic cavity
- Air is drawn into the lungs

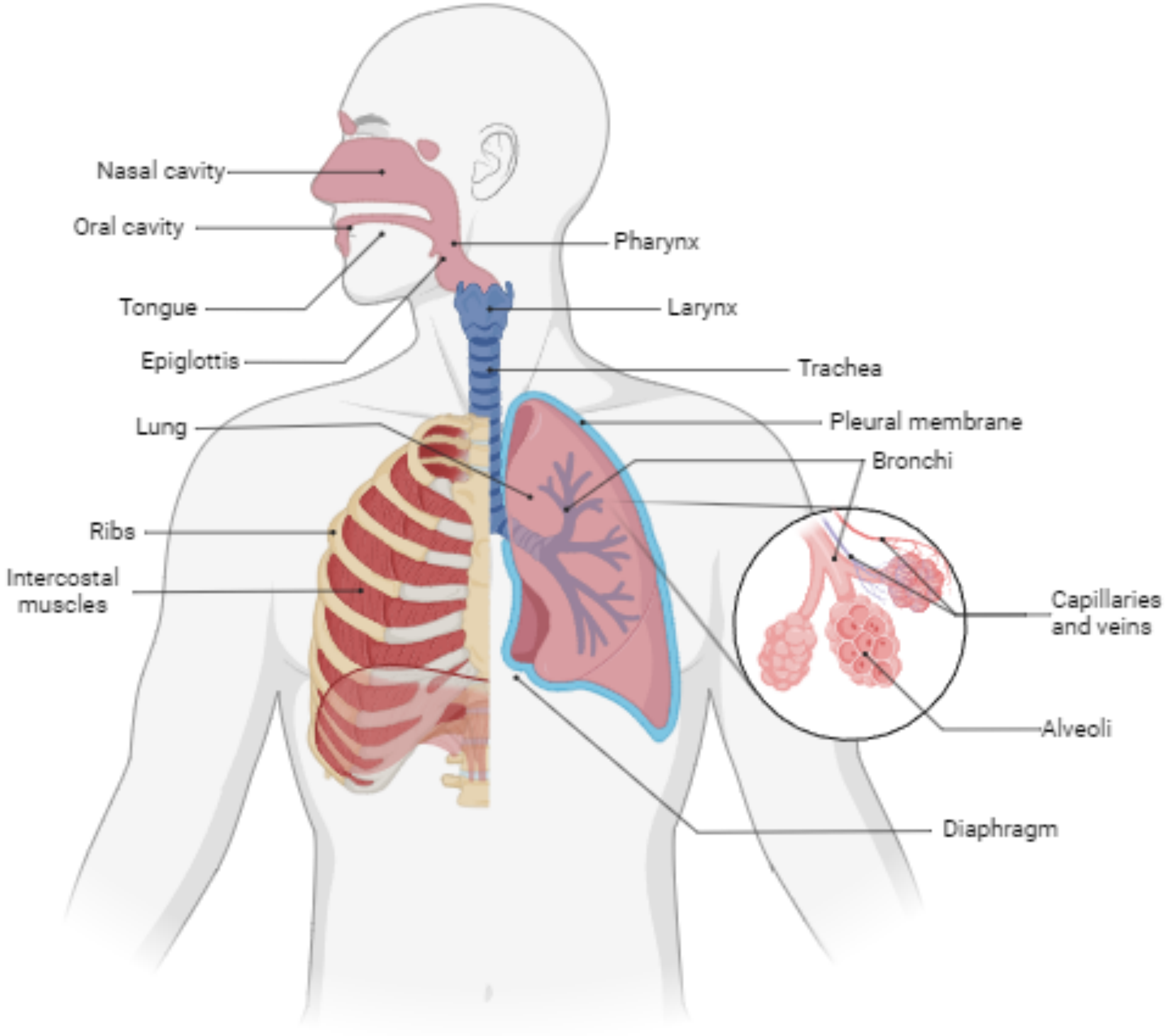
Expiration

- Muscles relaxes and lungs compress
- Air is expelled

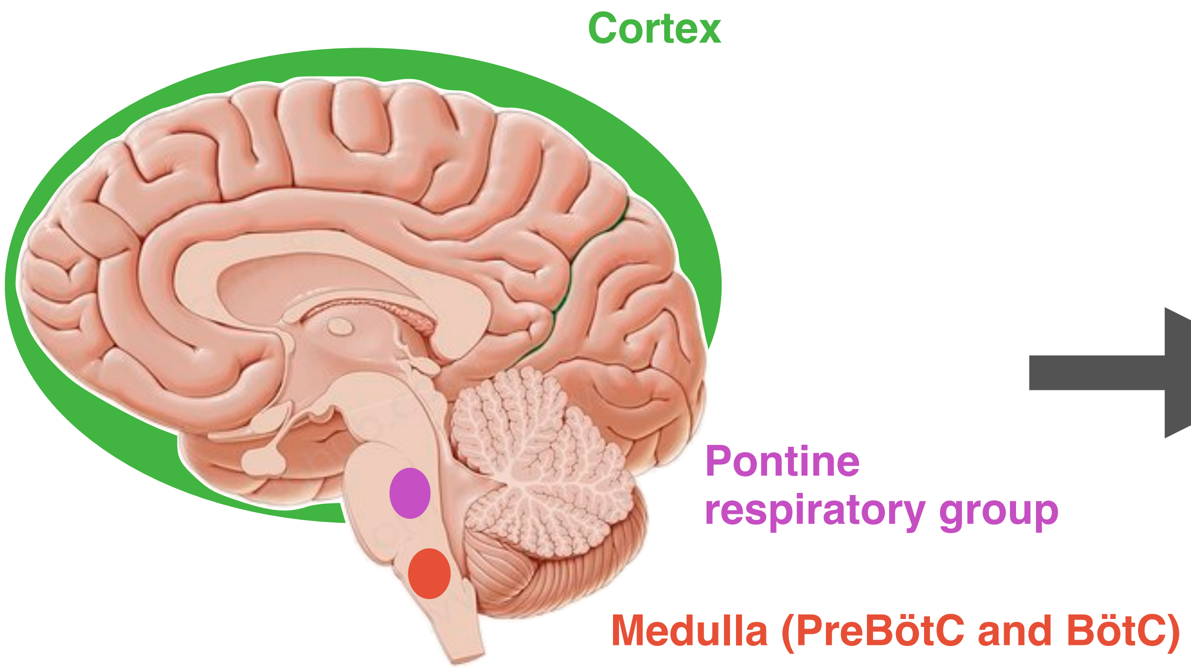
Measuring respiration

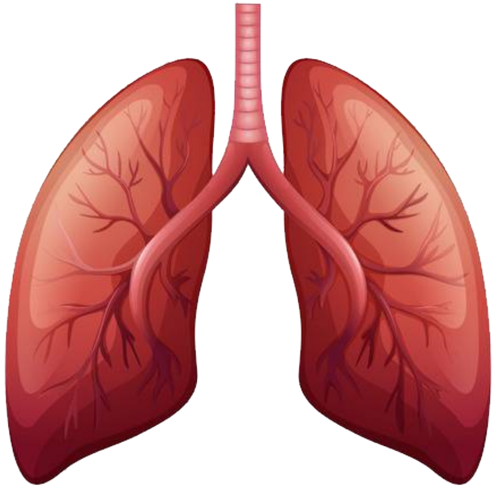
- Belt, pressure/temperature sensor

Automatic but can be put under voluntary control



RESPIRATION AND THE BRAIN





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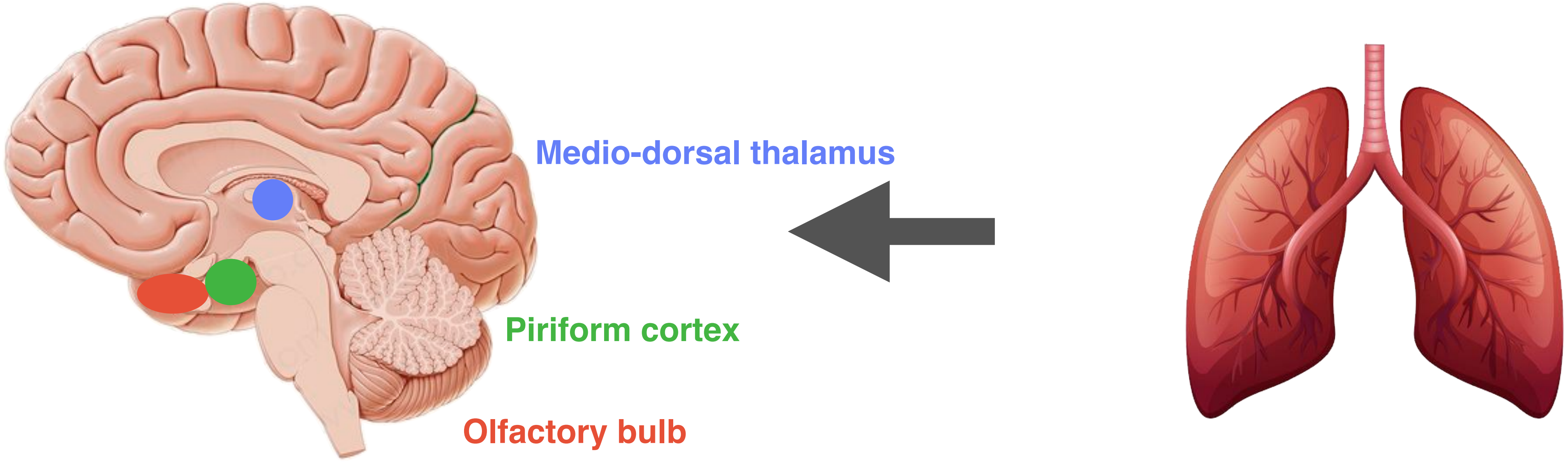

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BREATHING SHAPES BEHAVIOUR AND COGNTION

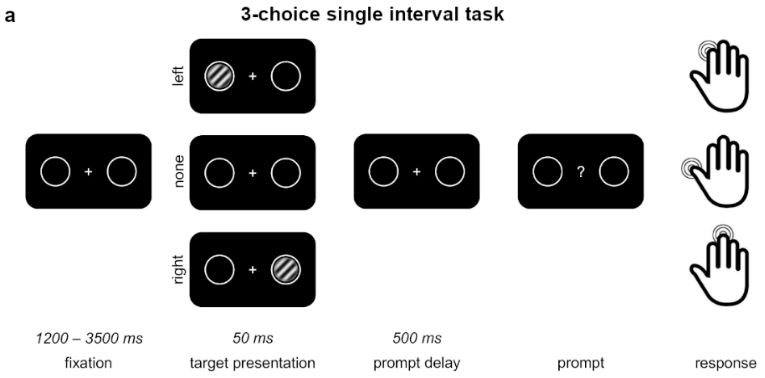
- Changes in visual and tactile perception with respiratory phase angles [1, 2, 3]

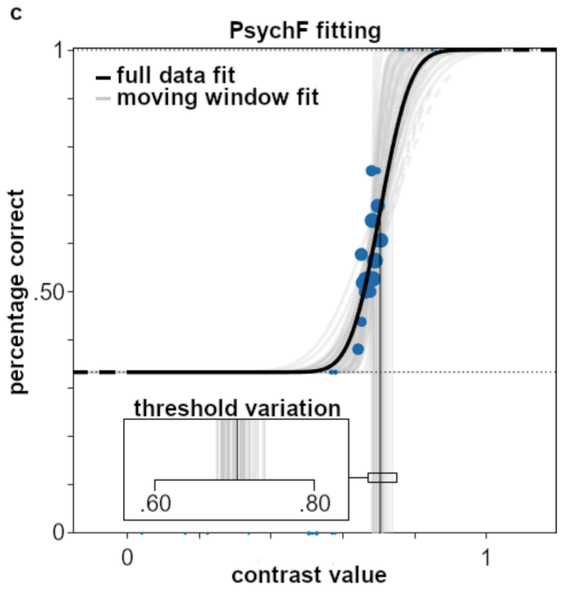
- Voluntary action and initiation of cognitive tasks around inhalation onset [4, 5]
- Faster response time during inspiration time locked to response [6]

[1] Kluger et al. (2021). Respiration aligns perception with neural excitability
[2] Chalas et al. (Preprint)
[3] Grund, et al. (2022). Respiration, Heartbeat, and Conscious Tactile Perception
[4] Park et al. (2020). Breathing is coupled with voluntary action and the cortical readiness potential
[5] Perl et al. (2019). Human non-olfactory cognition phase-locked with inhalation.
[6] Brændholt et al. (2024). The respiratory cycle modulates distinct dynamics of affective and perceptual decision-making.

CHANGES TO SENSORY PERCEPTION

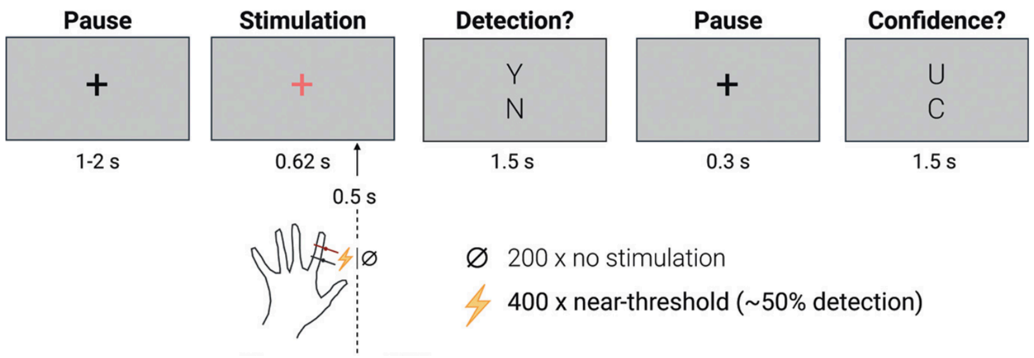
[1] Kluger et al. (2021). Respiration aligns perception with neural excitability
[2] Chalas et al. (Preprint). Respiration as a dynamic modulator of sensory sampling

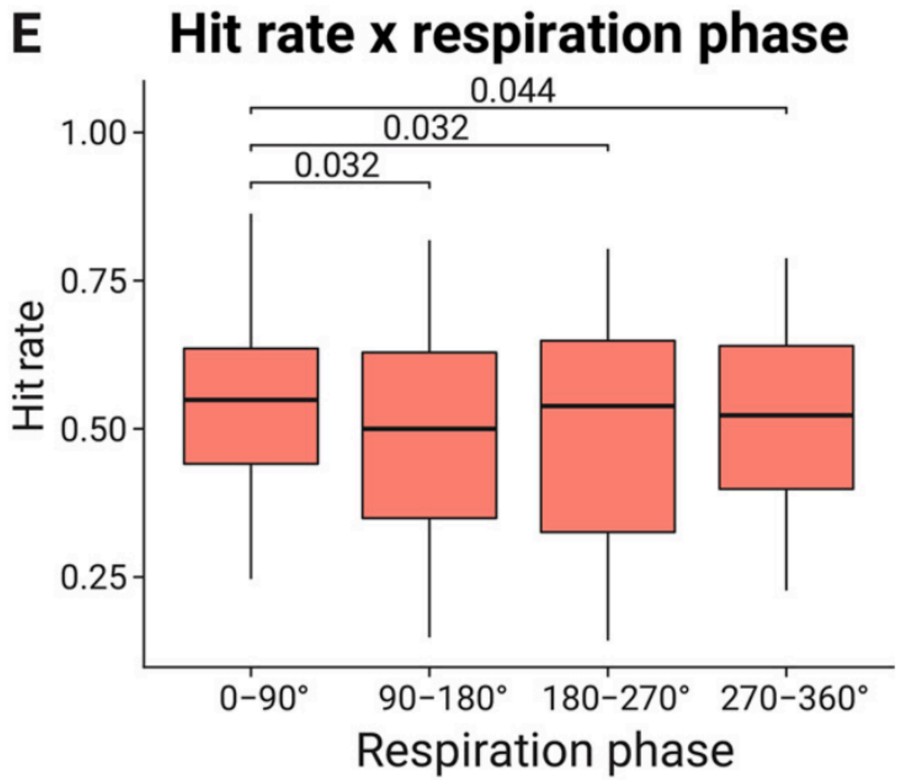




CHANGES TO SENSORY PERCEPTION

- Higher hit rate in the first quadrant after expiration onset compared to the three other quadrants





Grund, et al. (2022). Respiration, Heartbeat, and Conscious Tactile Perception

BREATHING SHAPES BRAIN OSCILLATIONS

Respiration-modulated brain oscillations (RMBOs) at rest

- Respiration modulates the global power of all frequencies between 2-150 Hz
- Localised to widespread network of cortical and subcortical regions
- Brain regions show modulation in different frequency bands and at different respiratory phases

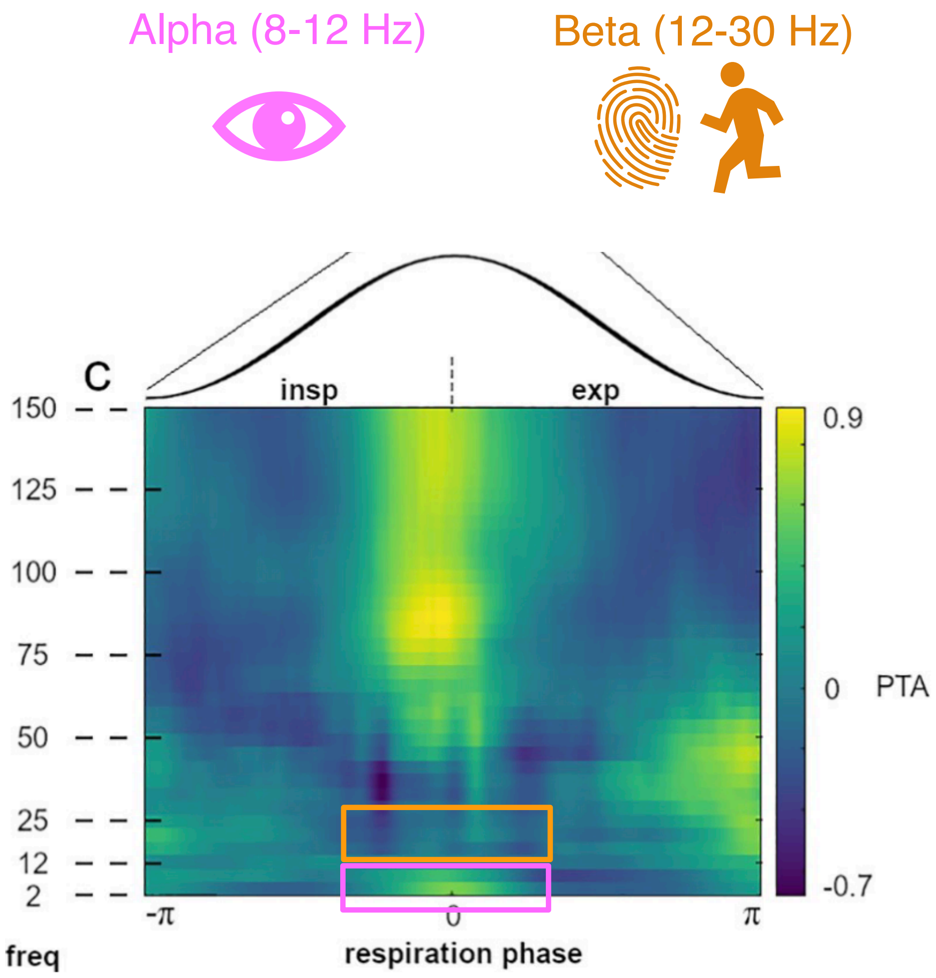


Figure from Kluger & Gross (2021)

GAP IN THE LITERATURE

- Timing often unpredictable or only cued shortly before onset
- Respiration effects often stronger when analysed time-locked to response rather than stimulus
- Slow respiratory cycle limits ability to align breathing with task

MY CURRENT PROJECT

& introduction to analysis of respiration data

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RESEARCH QUESTIONS

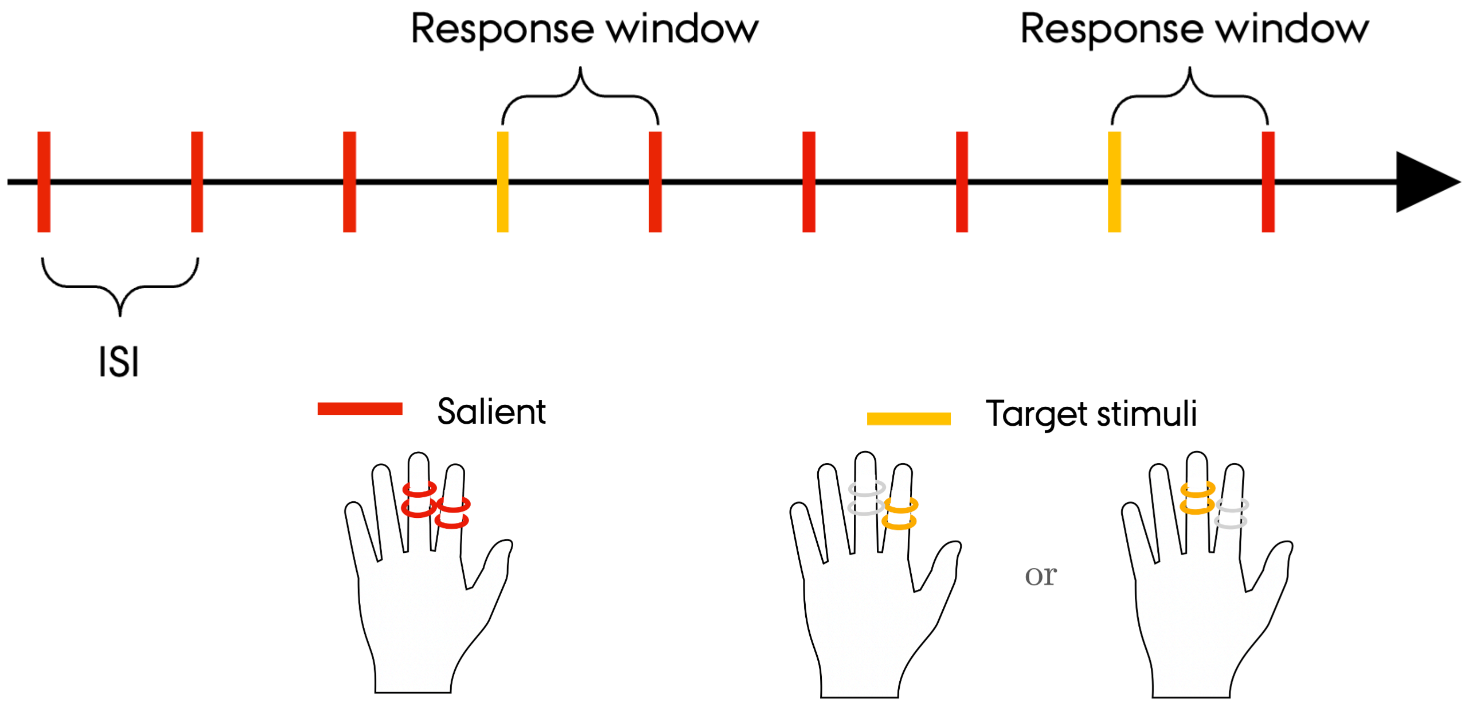
We ask two main research questions

(1) does respiration synchronise to the rhythm of external stimuli, showing a preferred phase within the respiratory cycle?

(2) does alignment has functional relevance, reflected in systematic variations in sensory threshold and response time across different phases of the respiratory cycle

PARADIGM

- ISI will vary in a blocklike structure
- Target intensity is adjusted throughout the experiment using adaptive QUEST staircase



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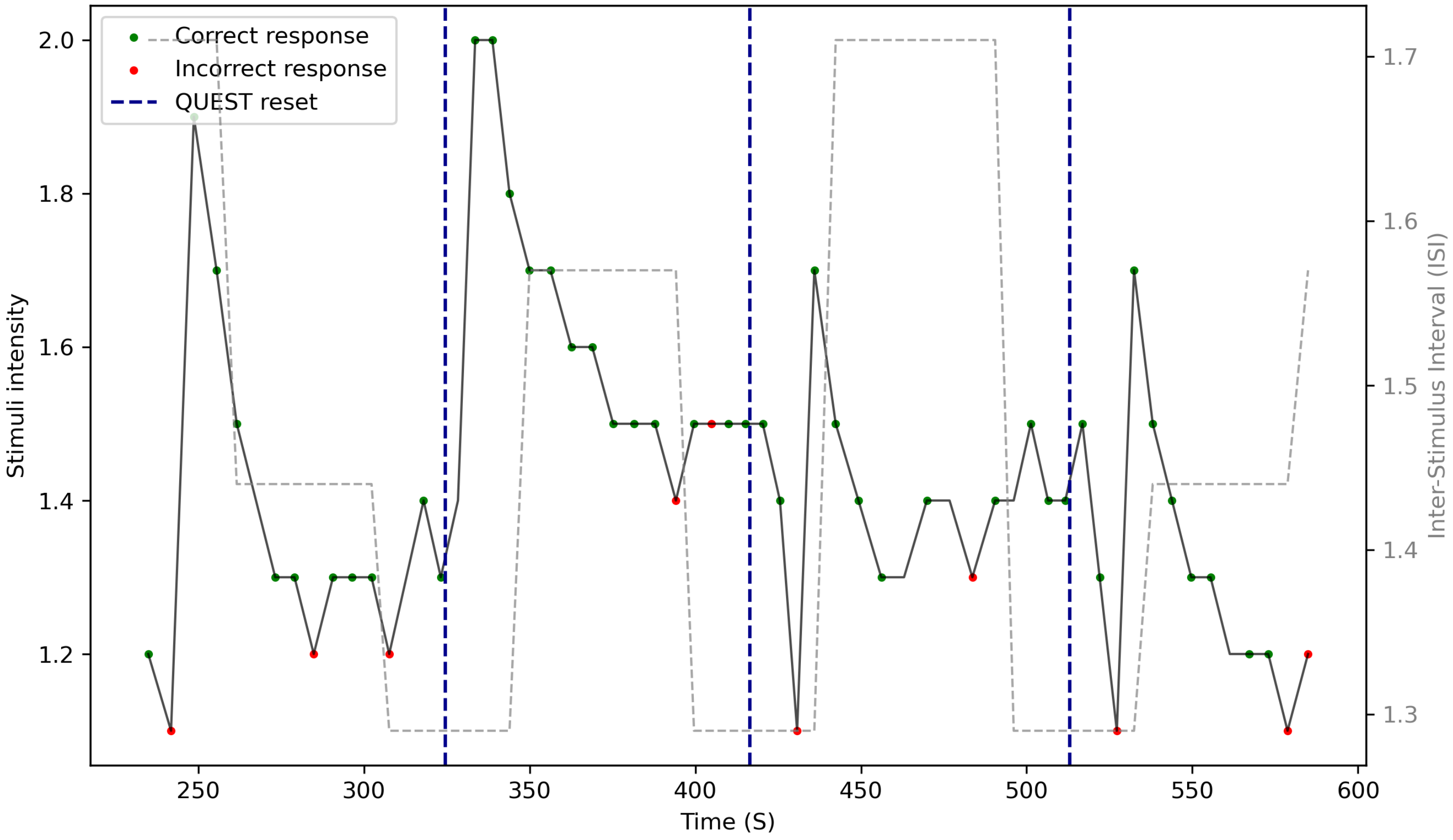

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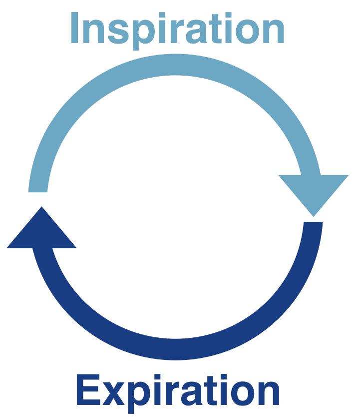
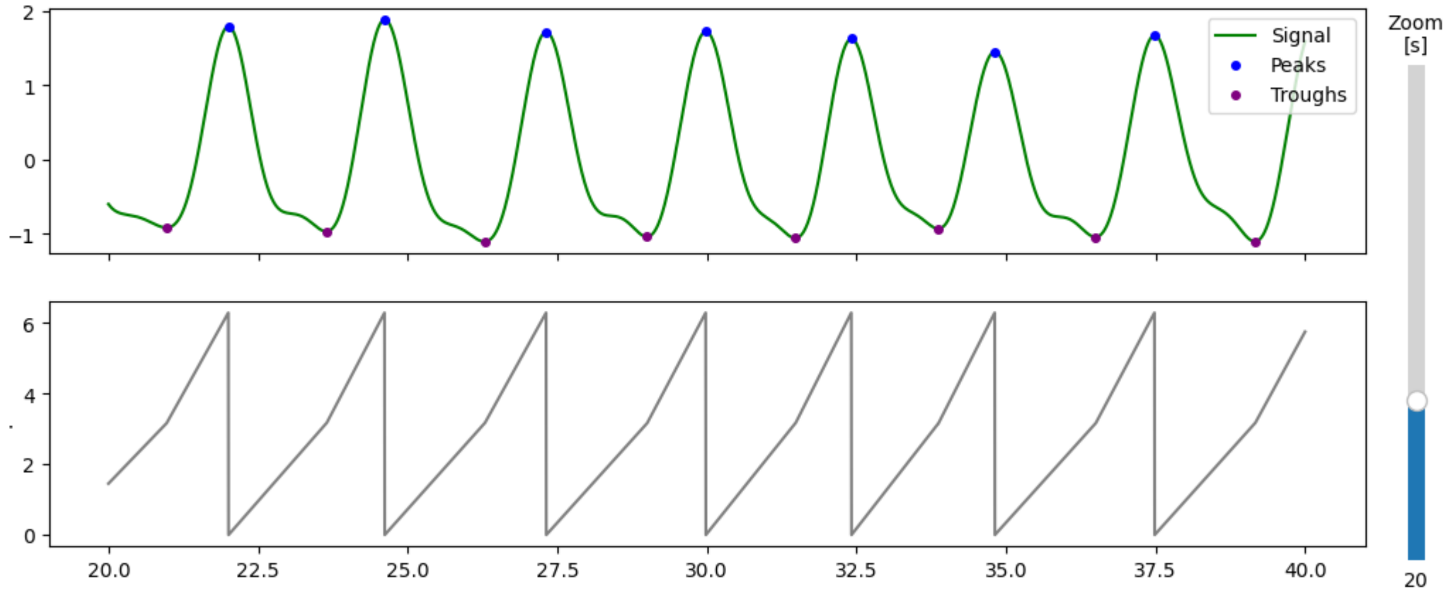
PREPROCESSING

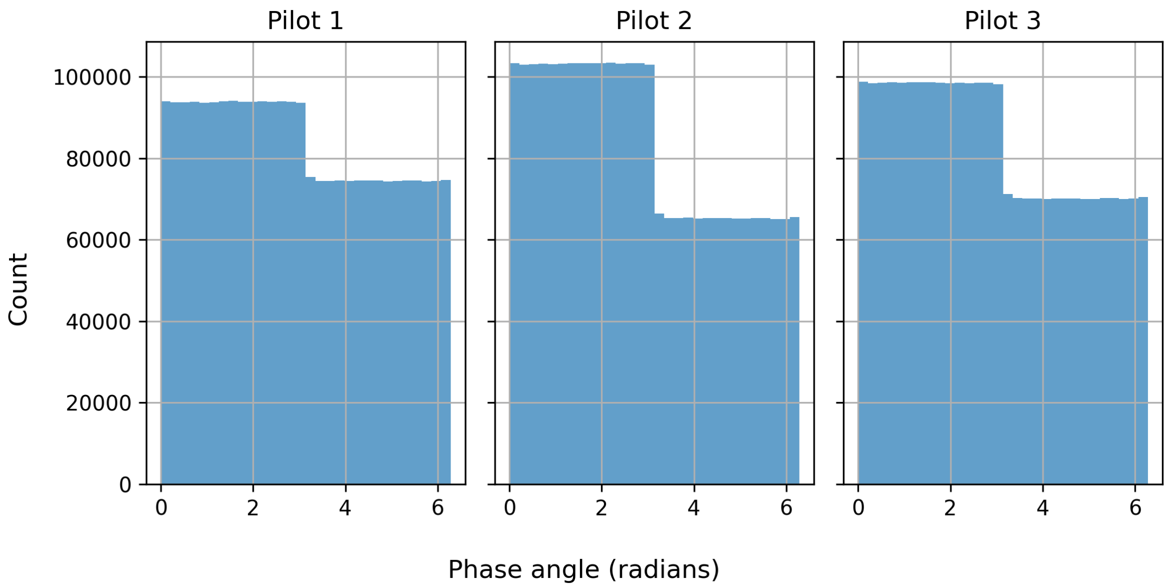
- Bandpass filter
- Smoothing kernel (average within a window)
- Transforming to circular data





TARGET EVENTS OCCUR AT PREFERRED RESPIRATORY PHASES

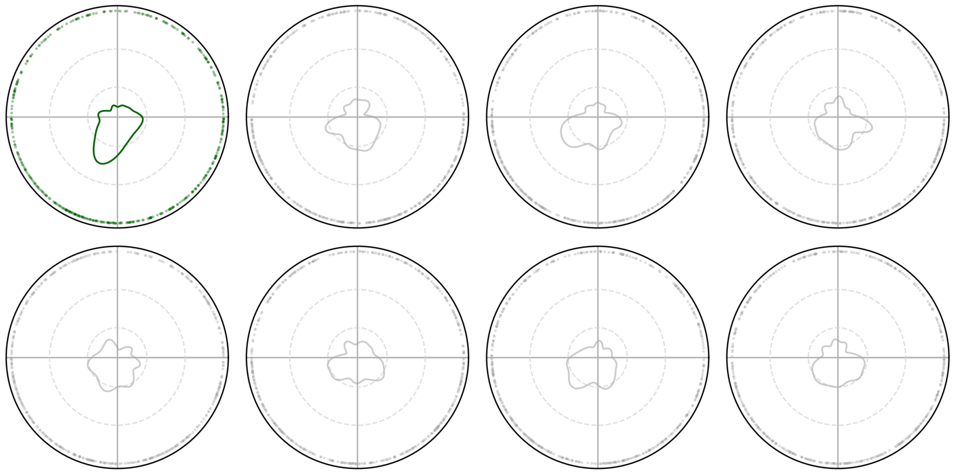
- Account for the non-uniform distribution of respiration phase

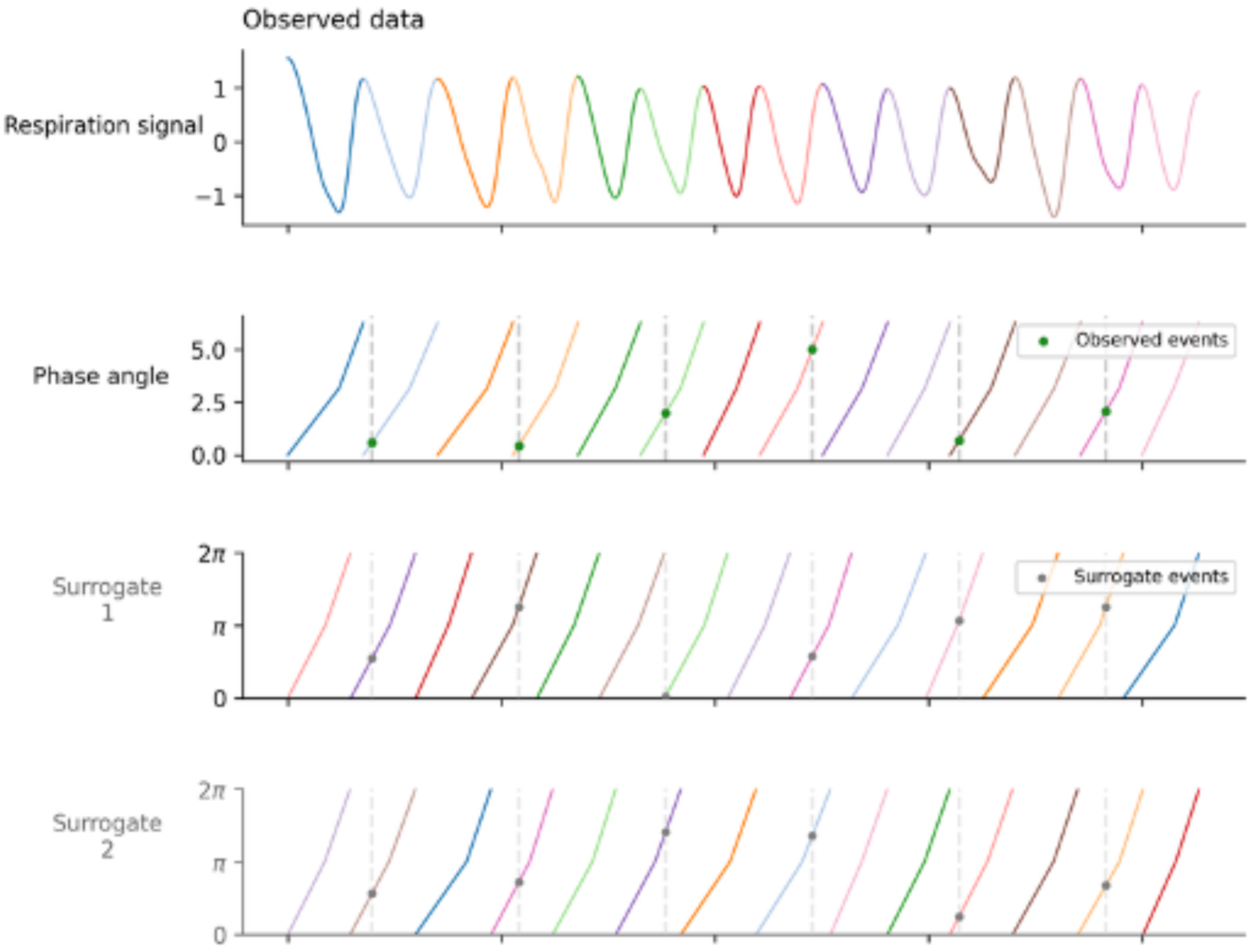


METHOD

Step 1: Generate surrogate samples of target events (n = 5000)

- Reordering of breaths segments and extracting event phase angles





METHOD

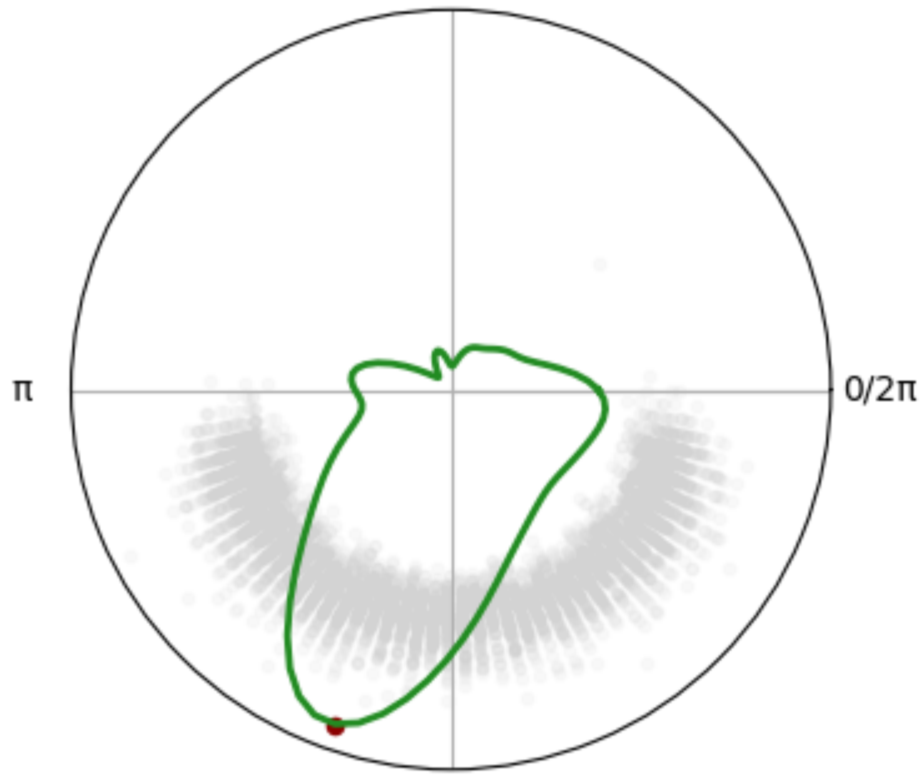
Step 2: Compute the maximum density for both the observed and surrogate samples

Step 3: Compute subject-level standardised *z*-score

- Quantifies how much the observed test statistic deviates from the null (surrogate) distribution
- Higher *z*-score = Higher maximum density than expected by chance

Step 4: Group-level statistical test

- Perform a one-sample *t*-test (*one-sided*, alternative = greater) across participants' *z*-scores



RESPONSE TIMES VARY WITH THE RESPIRATORY CYCLE

Modelling log(response time) using linear mixed effects model:

Log(rt) ~ sin_phase + cos_phase + (1 + sin_phase + cos_phase l participant)

- Significance testing:
  - Shuffle response times within each participant & refit model 10,000 times
  - p-value = proportion of null vector norms ≥ observed vector norm

- Interpretation**:** higher vector norm → stronger modulation of RT by respiratory phase

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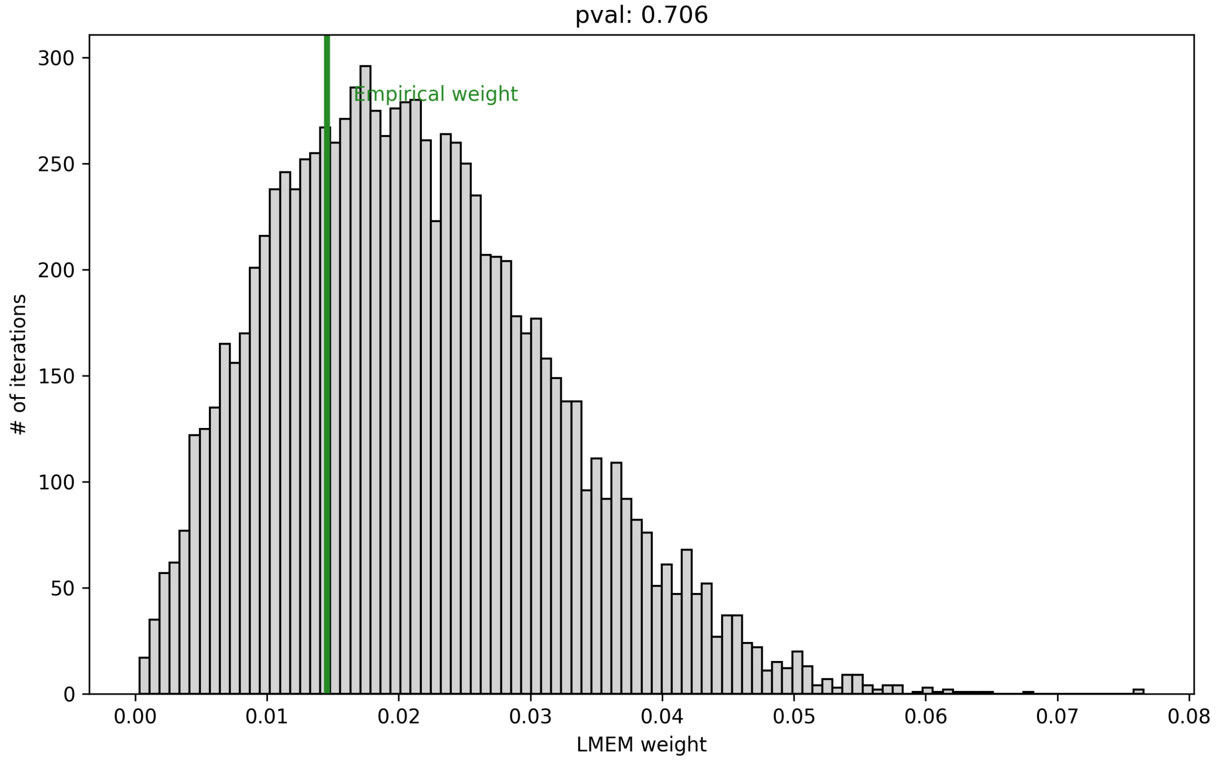
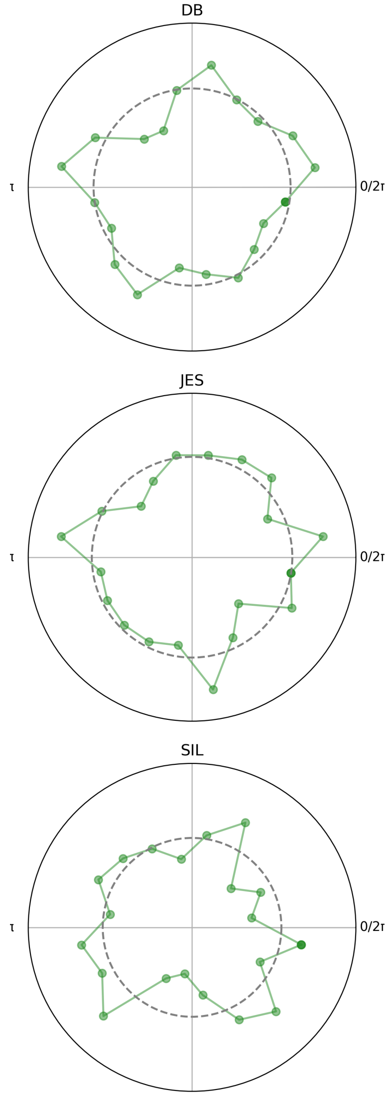
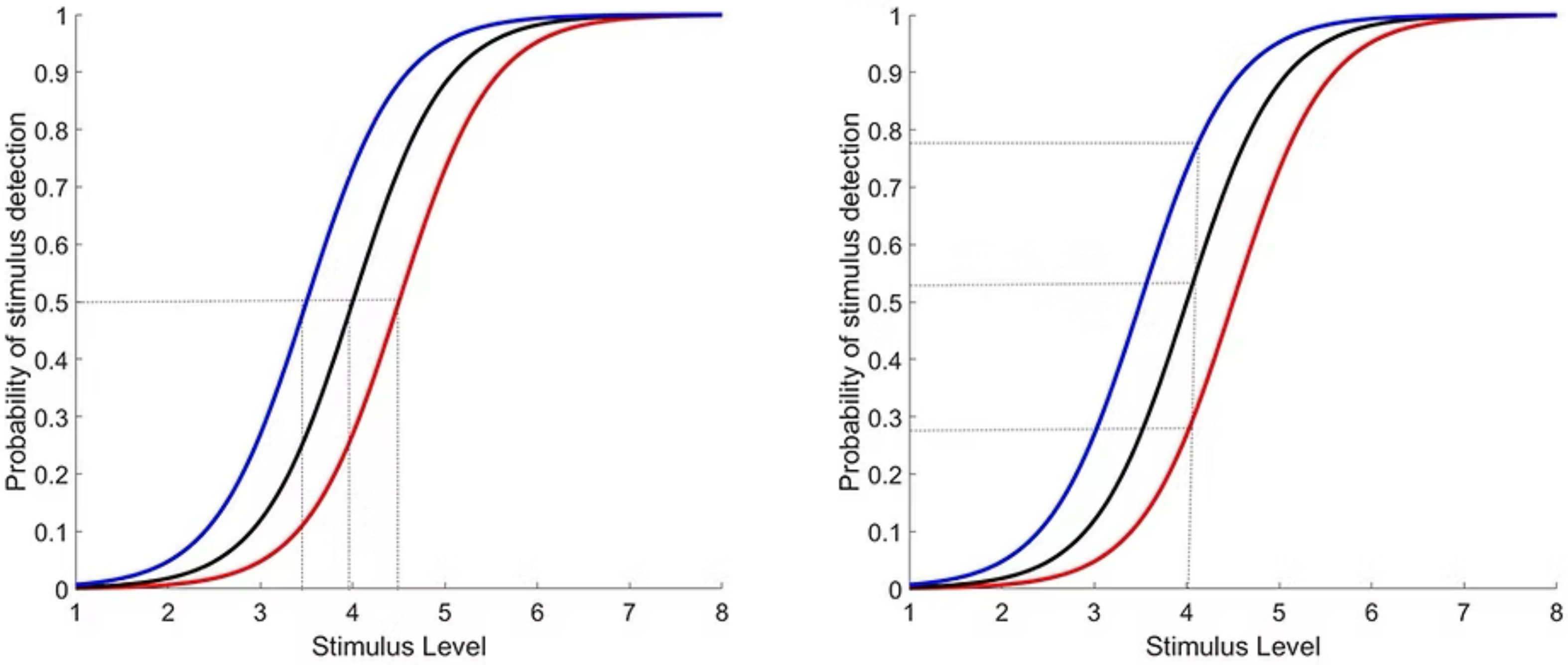
PILOT RESULTS





RESPIRATION INFLUENCES THRESHOLD FOR DETECTING WEAK STIMULI

- Describe the relationship between the intensity of the stimulus and detection at different respiratory phases - psychometric function!



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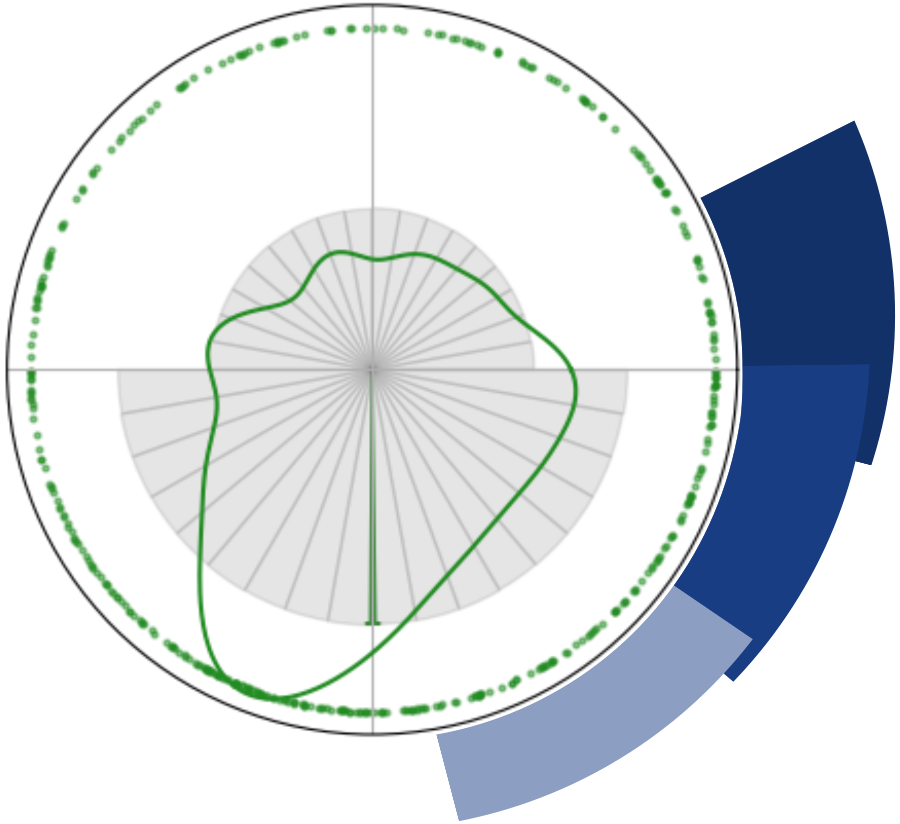
METHOD

- Fit Bayesian psychometric function (*psignifit*) for each participant
- Use **all trials** to estimate parameters of the psychometric function (lapse rate, slope, threshold)
- Fix all parameters except for threshold and refit using data from **specific respiratory phases**

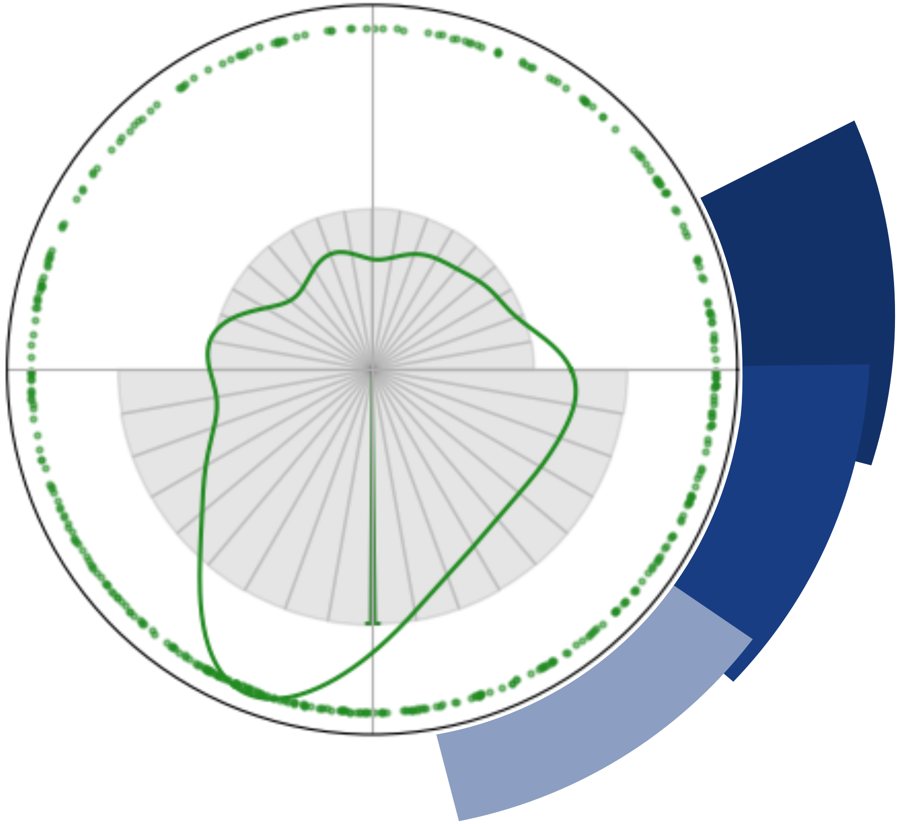


METHOD

Modelling thresholds using linear mixed effects model:

threshold ~ sin_phase + cos_phase + (1 + sin_phase + cos_phase | participant)

- Modulation magnitude: combine sine & cosine effects by calculating vector norm
- Significance testing:
  - Shuffle thresholds per participant & refit model 10,000
  - p-value = proportion of null vector norms ≥ observed



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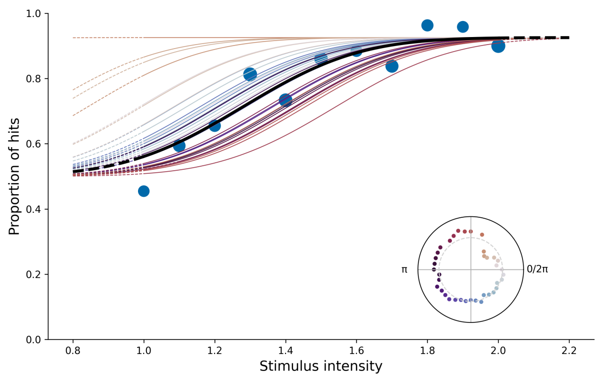

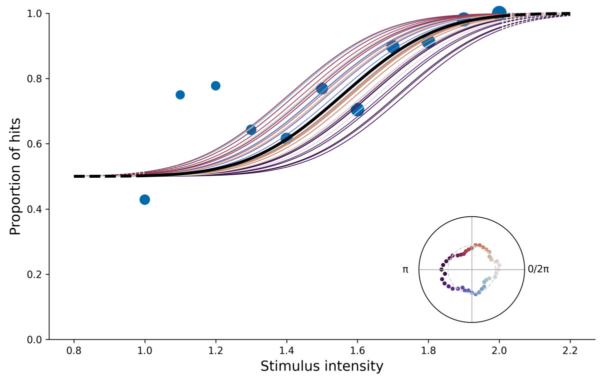

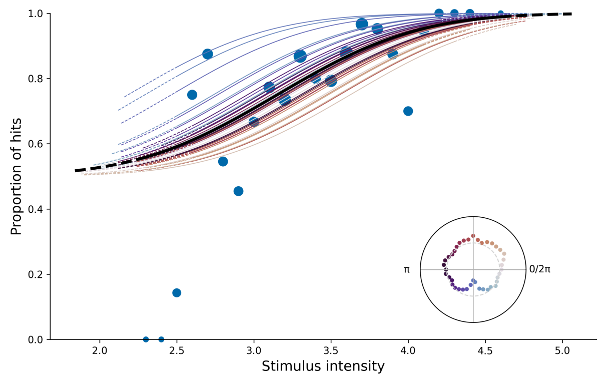

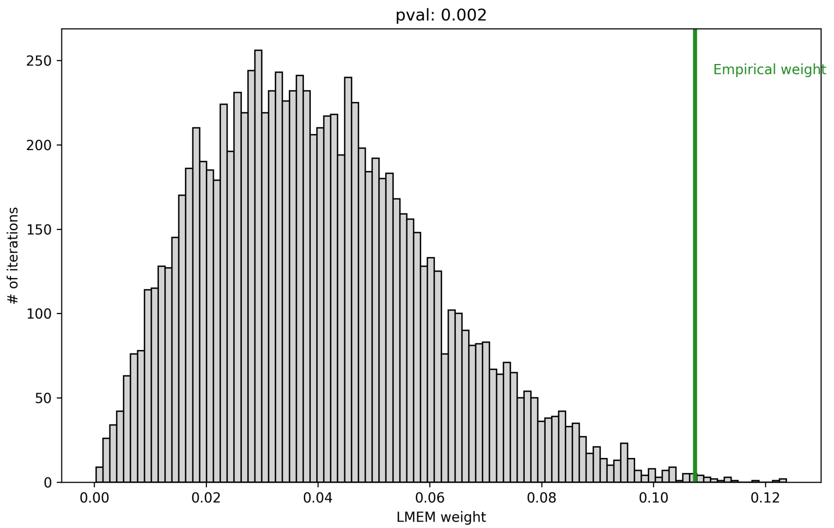

WORKING ON YOUR OWN RESPIRATION DATA!

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WORKING ON YOUR OWN RESPIRATION DATA!

1. Open uCloud
2. Pull from GitHub repository
3. Open the notebook (*W47_respiration.ipynb*) and work through it!

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Extra exercises

- Compare respiratory phase at different event types: Test whether the phase angles at *response times* differ systematically from the phase angles at *target onsets* — or choose any other pair of events you find interesting.

- Check for phase locking beyond chance: Test whether target stimuli occur at a preferred respiratory phase. You can get inspiration from this script https://github.com/laurabpaulsen/AnalysisBreathingBehaviour/blob/main/h1_phase-adaptation-target.py)