Asymmetries in the human inspiration/exhalation cycle relate to the nonsinusoidal waveforms of medial temporal lobe oscillations

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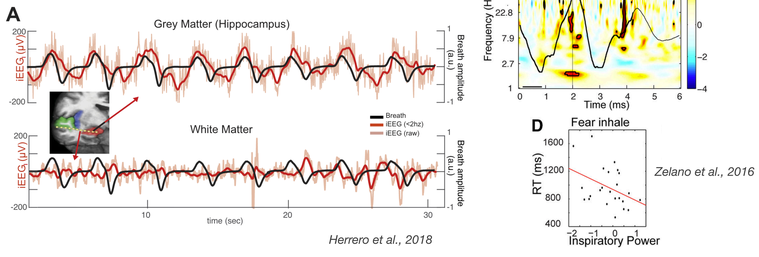
Background

- Breathing can entrain neural oscillations in regions typically implicated in cognition (hippocampus, amygdala, prefrontal cortex) (Tort et al, 2018, Herrero et al., 2018).
- Research in humans has shown improved task performance, in various cognitive domains, when subjects are in the inhalation, as opposed to the exhalation, phase of the respiration rhythm (Girin et al, 2021; Zelano et al., 2016; Arshamian et al., 2018).
- The strength of the respiratory modulation of subcortical neural oscillations is predictive of the improved task performance based on respiration phase (Zelano et al., 2016).
- Neural oscillations are nonsinusoidal and these waveform shape features are hypothesized to reflect the underlying neural physiological generators (Cole & Voytek, 2017).
- Respiration is also nonsinusoidal, yet these waveform features have been largely unexplored.



Herrero et al., 2018

Zelano et al., 2016

Dataset

Neural data:

- Stereoelectroencephalography (sEEG) electrodes implanted in hippocampus and amygdala.

Respiration data:

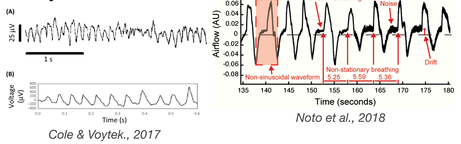
- Spirometer with a piezoelectric pressure transducer attached to a nasal cannula.

15 minutes resting.

Participant	Age	Hipp. Contacts Total (This Analysis)	Amyg. Contacts Total (This Analysis)	Epilepsy Duration Years	Epileptogenic Zone
1	29	6(1)	5(1)	7	Left temporal lobe
2	48	5(1)	3(0)	*Unknown*	Right temporal
3	32	7(2)	5(2)	10	Left basal temporal
4	27	9(2)	5(2)	5	Left mesial temporal
5	54	6(2)	4(2)	2	Right mesial temporal
6	25	7(2)	7(2)	3	Left mesial temporal

Neural Oscillation and Respiration Waveform Shape

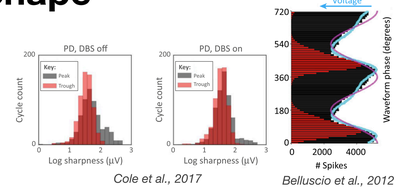
Neural oscillations and respiration are both periodic rhythms that are non-stationary, nonsinusoidal, and idiosyncratic.



Cole & Voytek., 2017

Noto et al., 2018

We hypothesize that the respiratory waveform drives the neural oscillatory waveform shape.



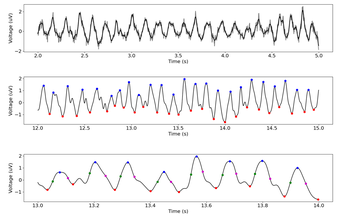
Cole et al., 2017

Belluscio et al., 2012

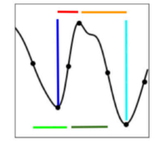
The nonsinusoidal features of neural oscillations are non-trivial, and have been hypothesized to inform underlying physiological and pathological characteristics (Cole & Voytek, 2017).

Cycle-by-Cycle Parameterization

Oscillations and respiration rhythms were parameterized on a cycle-by-cycle basis using bycycle (Cole & Voytek, 2019).



Cole & Voytek., 2019



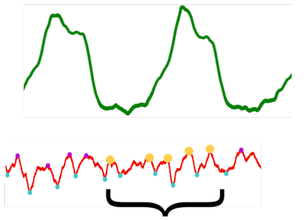
Amplitude = (| + |) / 2

Period = — + —

Rise-decay symmetry = —/(— + —)

Peak-trough symmetry = —/(— + —)

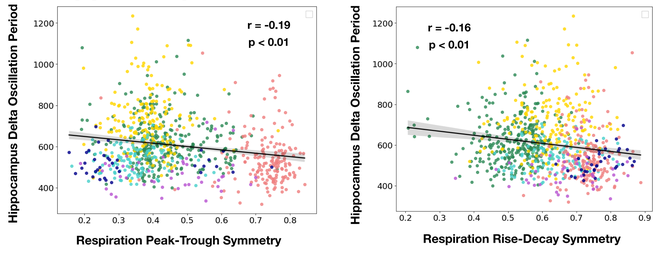
Neural cycles were aligned to each respective respiration cycle in time.



Five neural cycles aligned to this respiration cycle

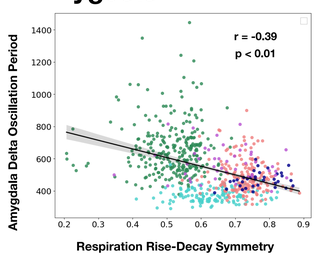
Respiration Waveform Asymmetries Correlate with Delta and Theta Period

Hippocampus

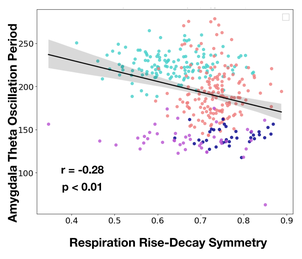


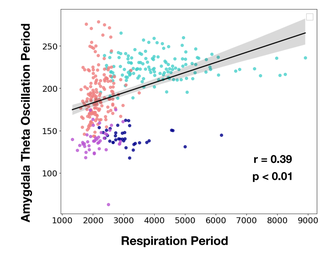
Hippocampal delta period is negatively correlated with respiration peak-trough symmetry and rise-decay symmetry.

Amygdala



Amygdala delta period is negatively correlated with respiration rise-decay symmetry.

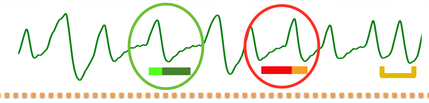




Amygdala theta period is negatively correlated with respiration rise-decay symmetry, and positively correlated with respiration period.

Participant 1 · Participant 2 · Participant 3 · Participant 4 · Participant 5 · Participant 6

Peak-Trough Symmetry: time in cycle during the peak
Rise-Decay Symmetry: time in cycle spent rising
Period: duration of the cycle



Although we find these correlations across subjects, these relationships are less powerful at an individual subject level, as indicated by the color coded plots by subject.

Conclusions

- Previous research has shown that there are respiration-entrained rhythms in the medial temporal lobe.
- We find significant relationships between asymmetric respiration waveform features and neural oscillation periods.
- However, these findings largely disappear at a single-subject level, suggesting that the influence of respiratory waveform shape on neural oscillations is a trait-level effect.

Future Directions

- We have established a trait-level correlational relationship between respiration and neural oscillation shape; therefore, our next steps are to determine any causal relationships between these waveform shape features within participants.
- Respiration is one of the only physiological signals humans can consciously control.
- Does changing the shape of your breathing change the shape of your neural oscillations? And how might those changes influence cognition?

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