MRC Cognition and Brain Sciences Unit

UNIVERSITY OF CAMBRIDGE

The Measure and Analysis of Respiratory Effort

COGNESTIC 2023

Alexis Deighton MacIntyre

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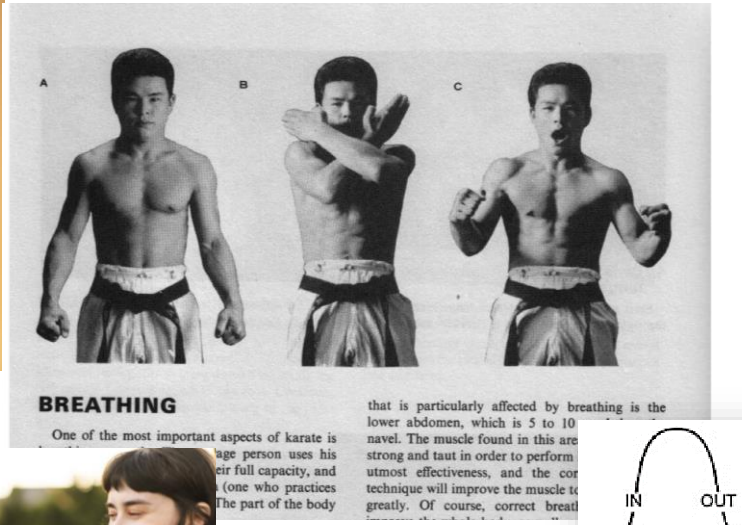
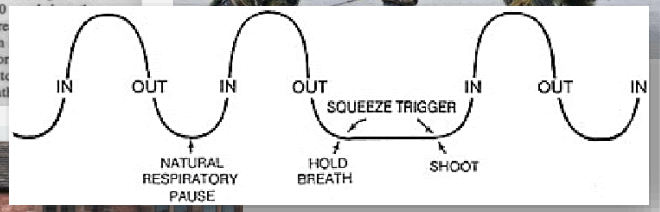
Background

Breathing as Human Behaviour





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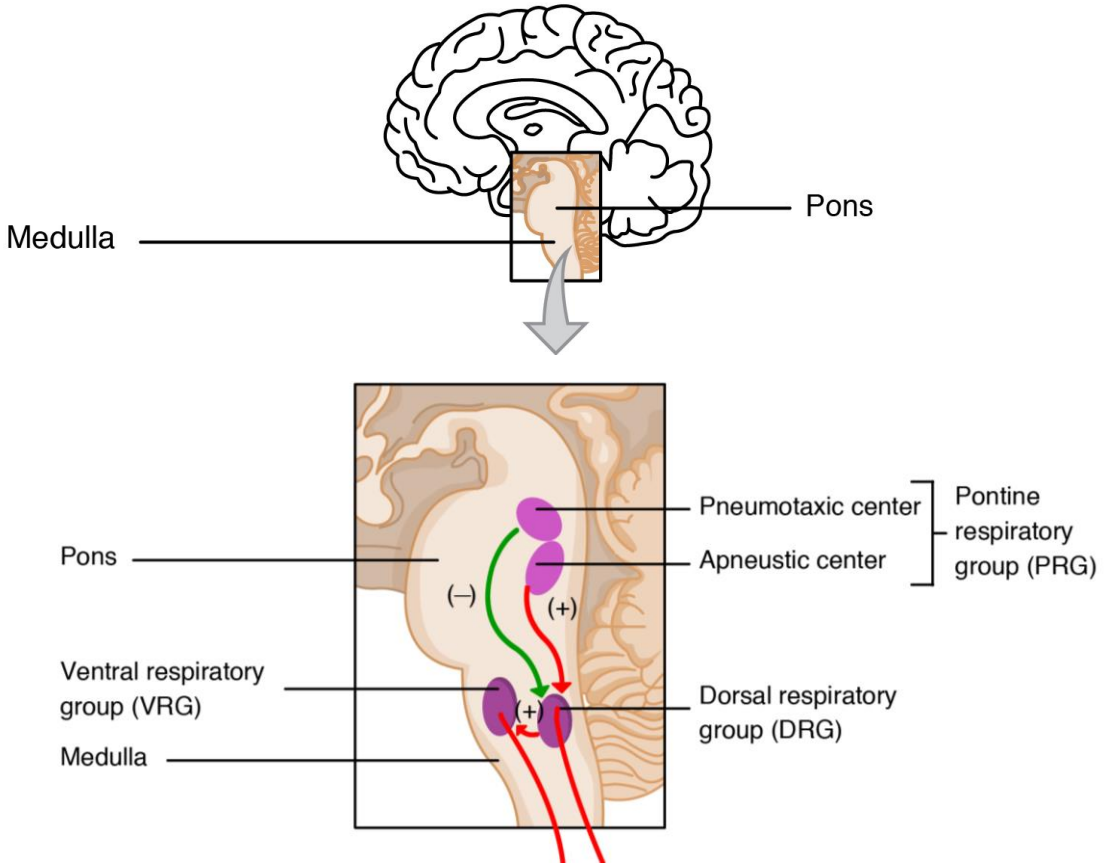
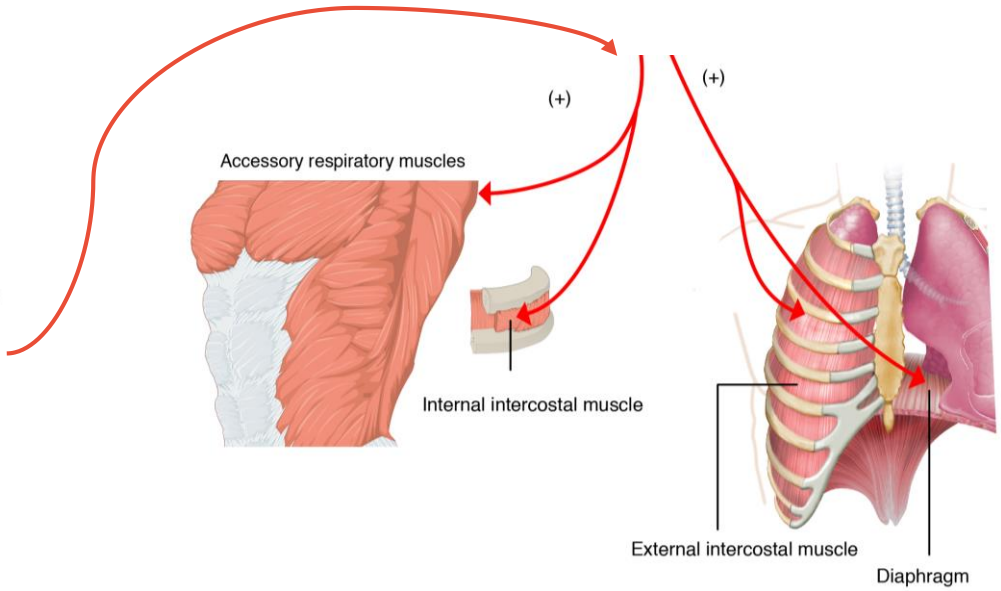
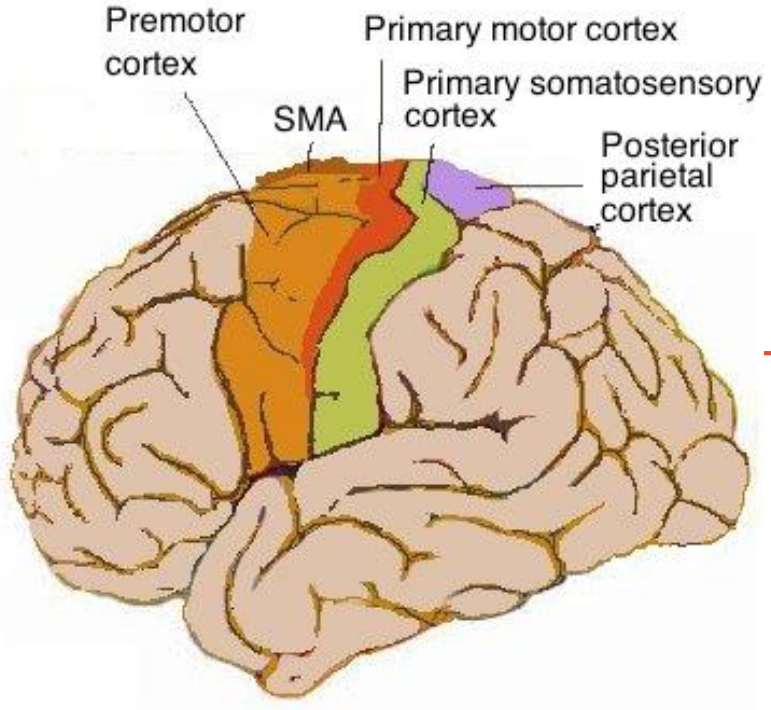
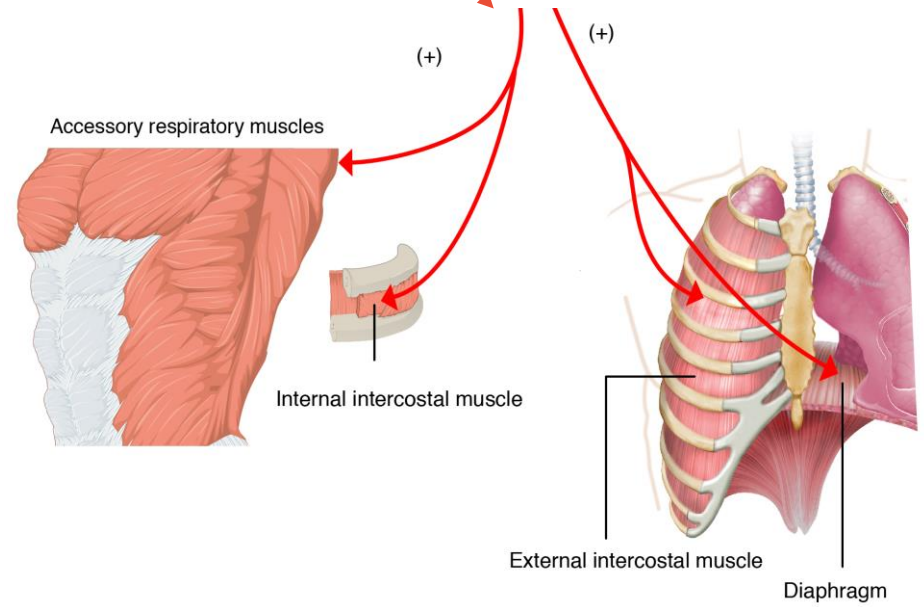
How does the brain control breathing?





How does the brain control breathing?





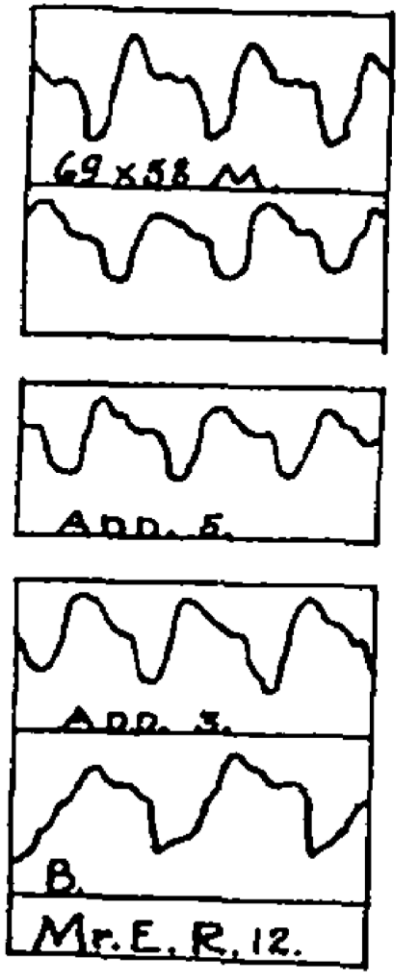
Scientific Interest in Breathing: Early 20th Century

Journal of
Experimental Psychology

VOL. I, No. 5. OCTOBER, 1916

THE EXISTENCE AND FUNCTION OF INNER SPEECH IN THOUGHT PROCESSES

BY H. B. REED
University of Idaho



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Scientific Interest in Breathing: Mid-20th Century

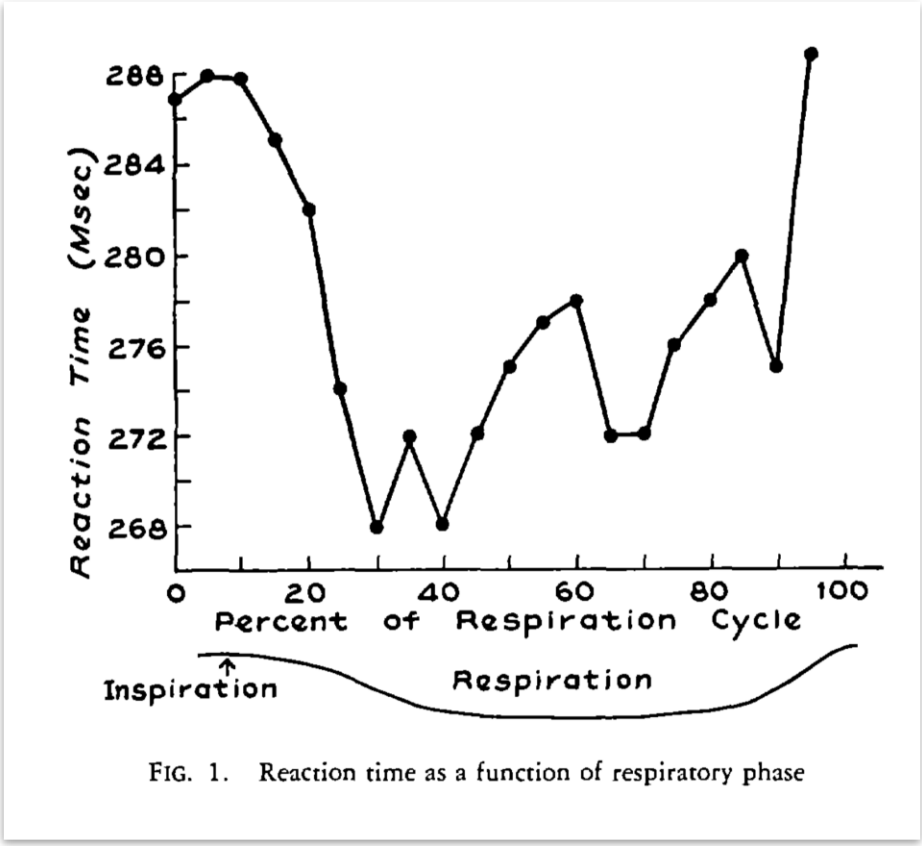


FIG. 1. Reaction time as a function of respiratory phase

Perception & Psychophysics
1974, Vol. 16 (2), 337-339

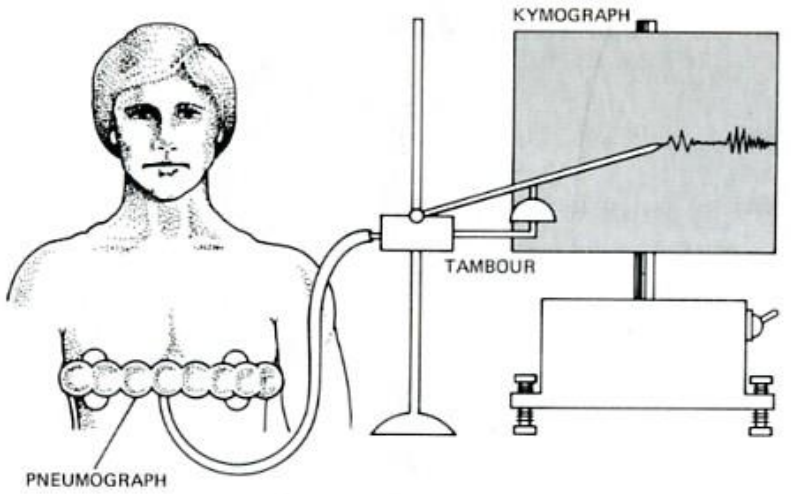
Respiratory phase and visual signal detection

JERRY E. FLEXMAN*
Department of Psychology

and

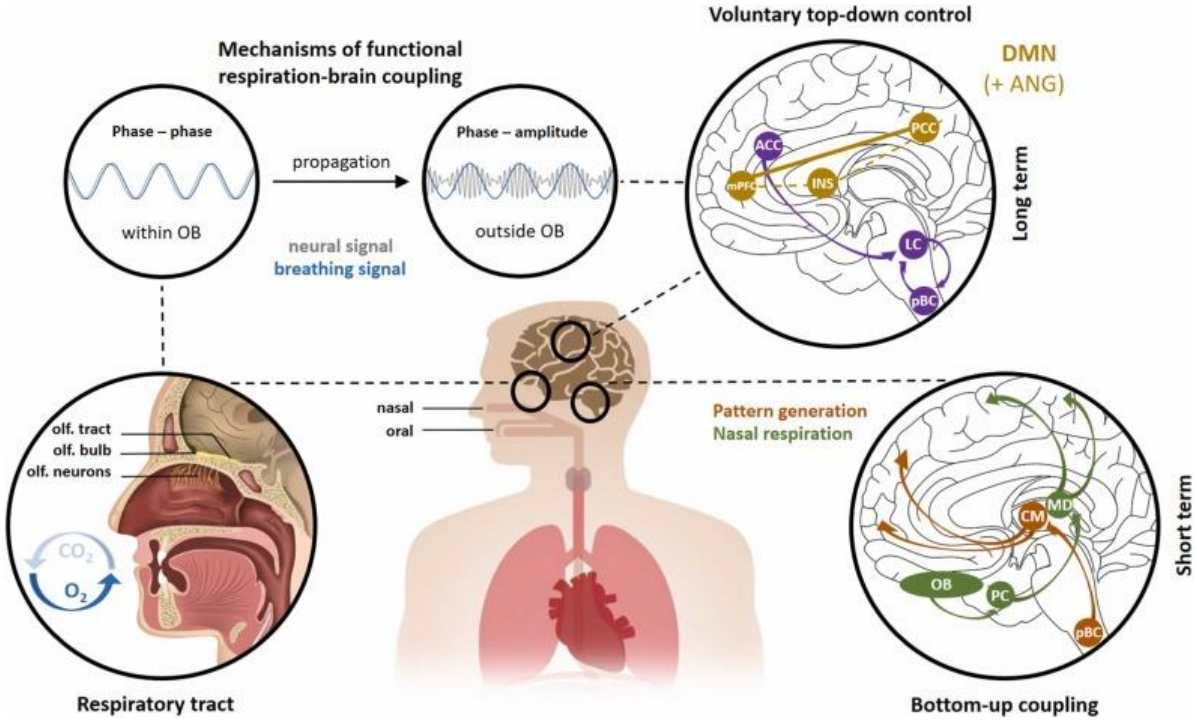
ROBERT G. DEMAREE and D. DWAYNE SIMPSON
Institute of Behavioral Research
Texas Christian University, Fort Worth, Texas 76129

Previous studies have implicated respiration as a source of intra-S variation in visual signal detection tasks. In the present study, pneumographic respiration records were obtained on 22 female undergraduates during a visual signal detection task. The analysis of signal detection with respect to respiration phase showed that signals presented during exhalation were detected more frequently than those presented during inhalation. These findings suggest that the intra-S variation in signal detection performance may be partially accounted for by respiratory behavior at the moment of signal presentation.



Scientific Interest in Breathing: Early 21st Century

- In humans, modulatory effects of respiration have been demonstrated in motor, sensory, and cognitive tasks.
- Bidirectional interplay between respiratory control and higher cognitive functions.
  - Respiration modulates neural oscillations across cortical and subcortical networks (including those not traditionally associated with olfaction).



Brændholt et al., 2023

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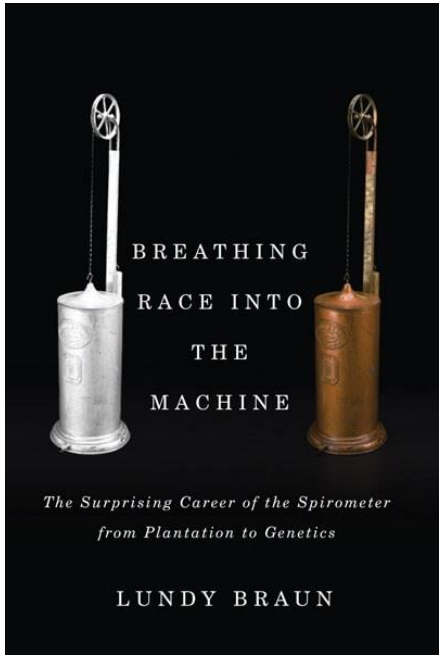
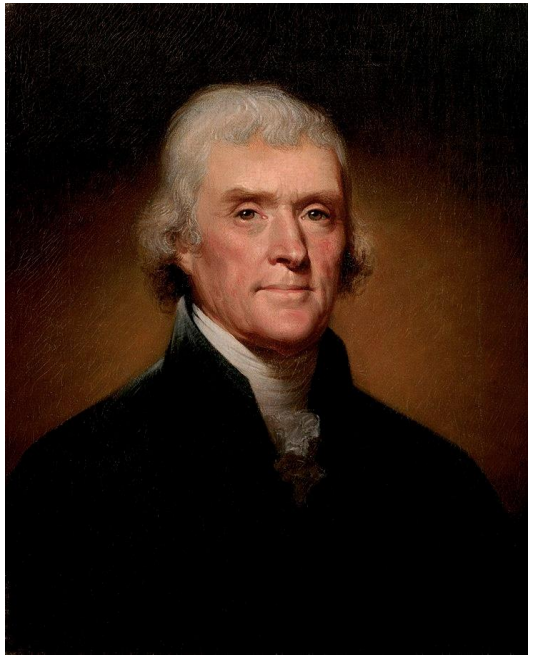
Methodologies

Respiratory measure and racial pseudo-science

“A difference of structure in the pulmonary apparatus”

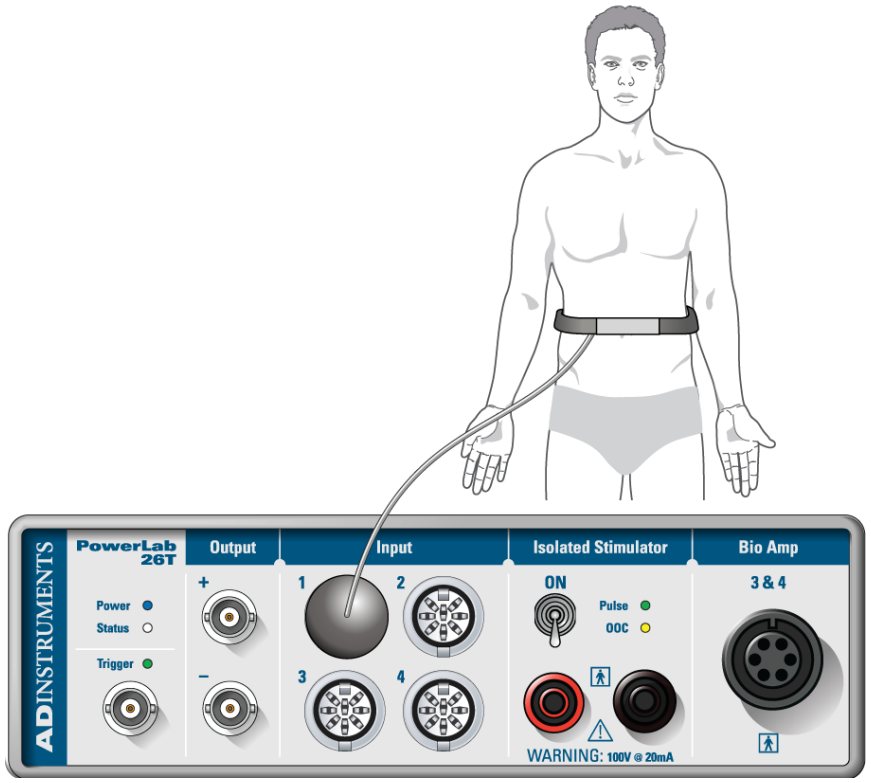


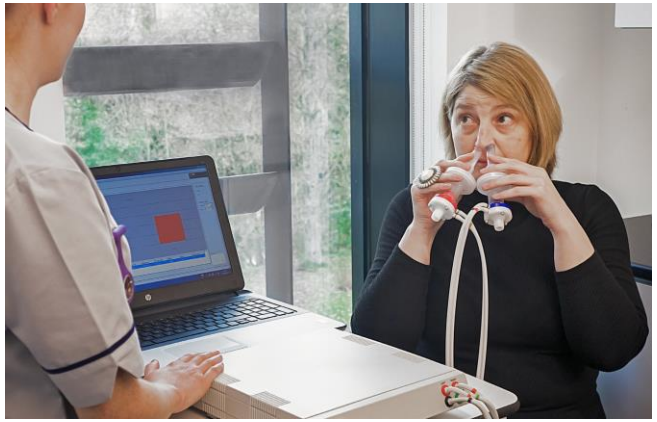


Average Capacity of Lungs.

	In usual Vigor		Not in usual Vigor	
	No. Men	Cubic Inches	No. Men	Cubic Inches
White Soldiers, Earlier Series	4 837	175.655	1 915	155.699
White Soldiers, Later Series	8 895	187.868	1 541	166.321
Sailors	1 104	179.217	–	–
Students	288	204.382	–	–
Full Blacks	1 631	165.319	221	149.697
Mulattoes	671	161.635	138	145.428
Indians	504	185.058	7	179.286

How can we measure breathing?

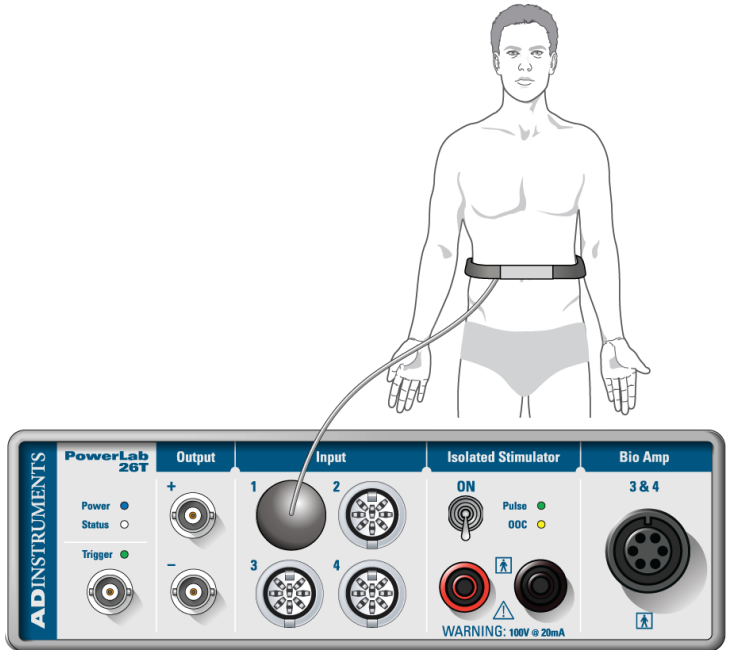




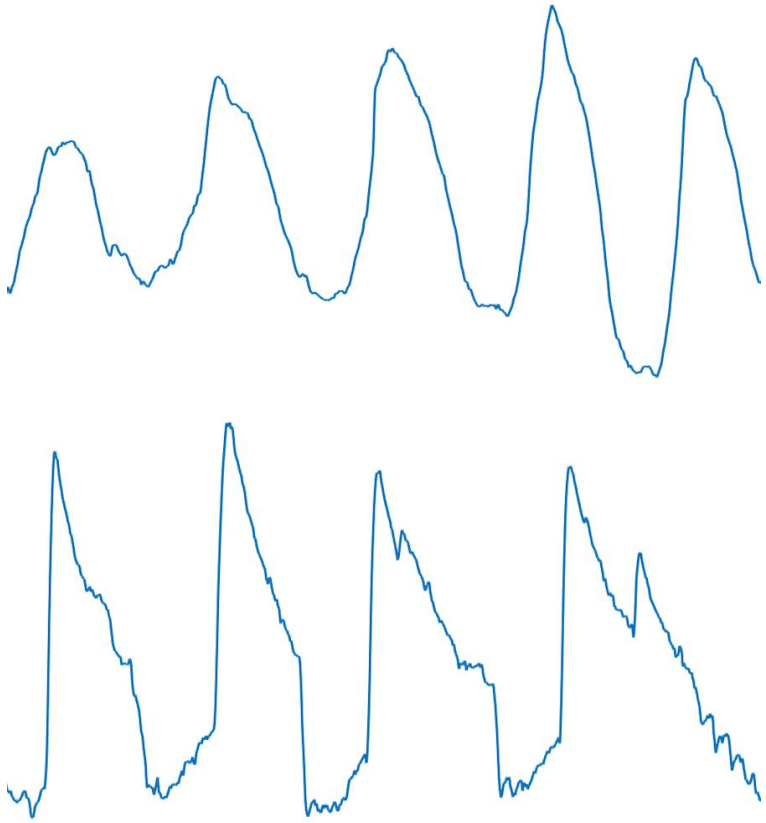
How can we measure breathing?

Getting a good signal from breath belts

- ✓ Use at least two belts (you don't know which one will work best)
- ✓ Ask participants to wear tightly fitting clothes
- ✓ Remove jewellery and avoid garments with wiring or metallic buttons
- ✓ Use a physical prop to control gesture or postural movements, especially for speaking tasks
- ✓ Remove sources of electrical noise
- ✓ Allow time for belt to "settle"



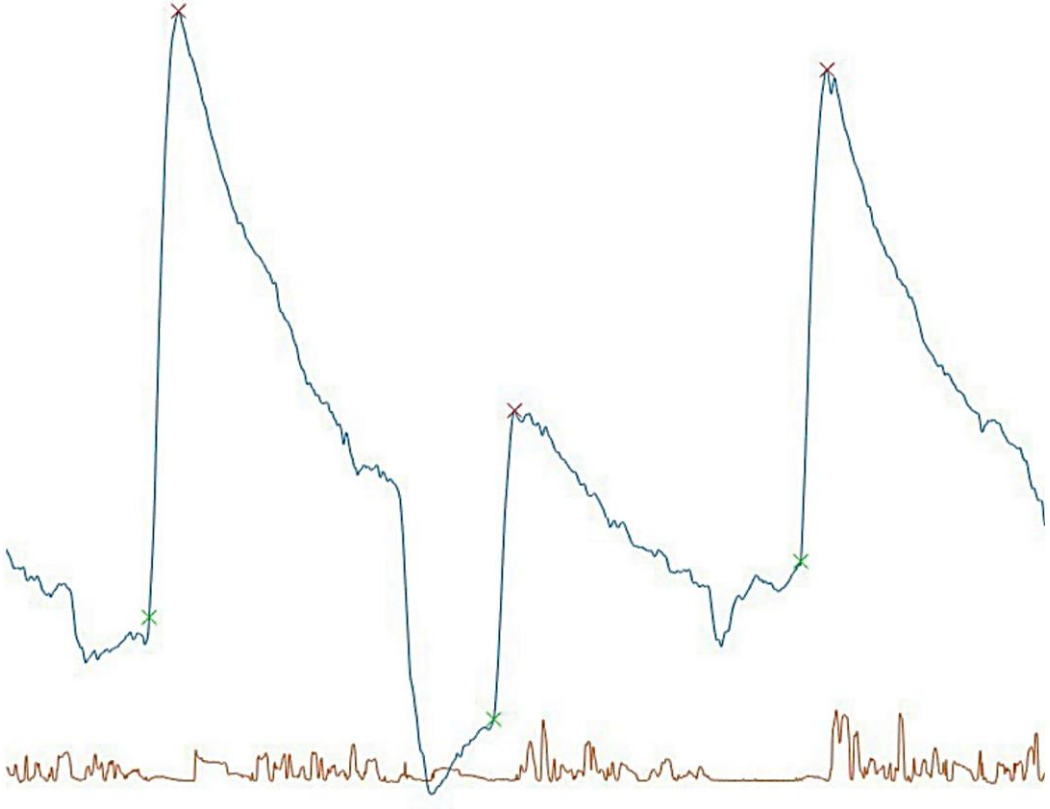
Annotation of the signal



Approaches reported in the literature:

- Manual annotation
- Take the zero-crossings of the acceleration of the respiratory signal within an appropriate bandwidth (e.g., 0.05 Hz – 10 Hz)
- Find the locations of values equivalent to 10% of the value of the velocity peak before and after the peak
- Take the “initial time point at which volume starts to change rapidly” and the terminus is then the point of ”maximal volume”

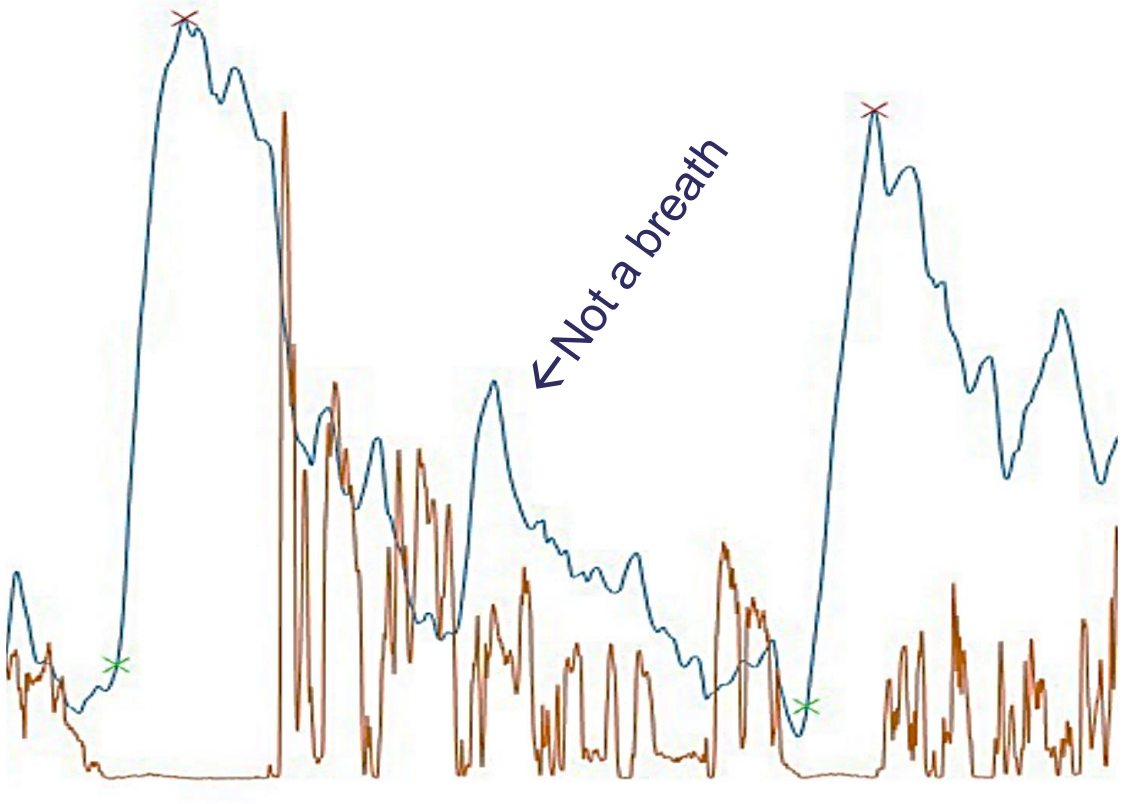
Pre-processing and Annotation



←Breath

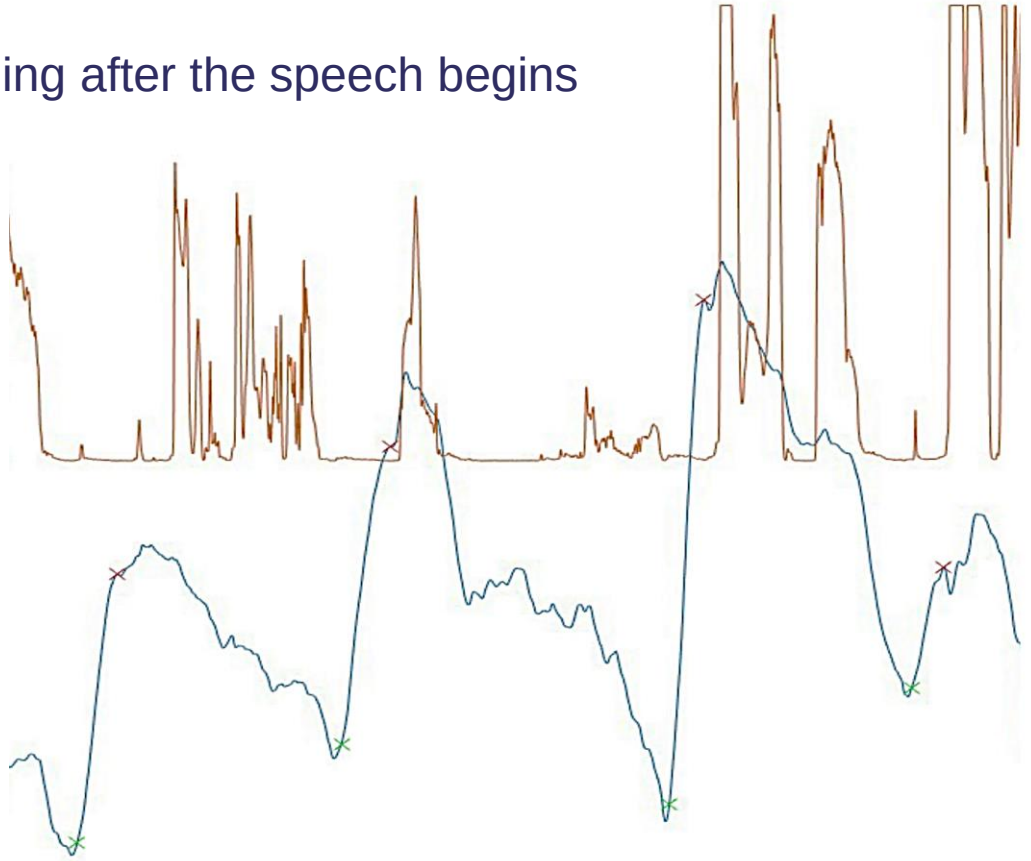
←Speech

Pre-processing and Annotation



Pre-processing and Annotation

Breath belt continues expanding after the speech begins



Pre-processing and Annotation

An Automatic Method for Speech Breathing Annotation

Alexis Deighton MacIntyre[1], *Raphael Werner*[2]

[1]*University of Cambridge*, [2]*Saarland University*
alexisdeighton.macintyre@mrc-cbu.cam.ac.uk, rwerner@lst.uni-saarland.de

Abstract: Breathing is central to speech planning and production; however, speech breathing is difficult to monitor and quantify without laborious and subjective manual annotation. Here, we describe a method for automatically detecting the beginning and end time points of speech-associated inhalations measured with inductive

https://github.com/alexisdmacintyre/SpeechBreathingToolbox

SpeechBreathingToolbox

Tools for the automatic detection of speech-related inhalation events and characterisation of the speech respiratory cycle.

Please cite as:

MacIntyre, A. D. and Werner, R. (2023). An Automatic Method of Speech Breathing Annotation. *Proceedings of the 34th Conference on Electronic Speech Signal Processing (ESSV)*, Munich, DE.

About

Use `findBreaths()` to automatically detect speech breathing onsets and ends, then optionally corroborate the results to the acoustic speech envelope using `breathSpeechCompare()`. Finally, you can use `plotBreaths()` to visualise the breath onsets and ends in relation to the breath belt signal and, if you have it, the corresponding acoustic data. This plot can help you decide if you need to adjust the default paramaters (e.g., minimum inter-breath interval).

Usage

Run `example.m` with included example breath belta data and acoustic recording to see how the scripts work.

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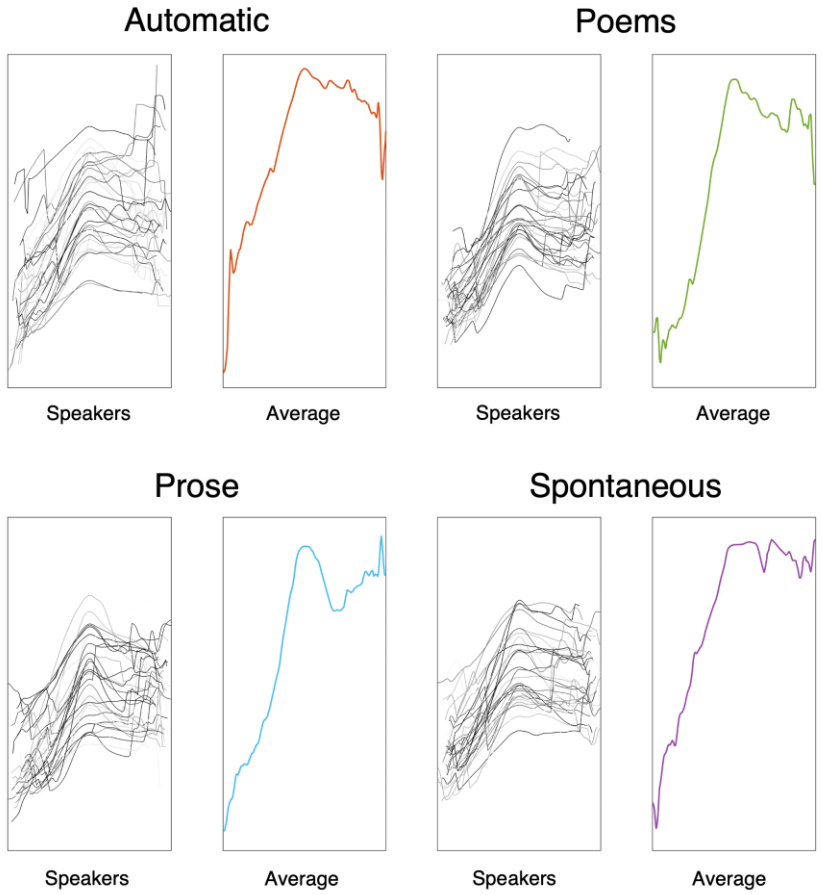
Dependent Variables

- Time series
  - Full cycle
  - Inhalation duration
  - Post-inspiratory period
- Volume
- Kinematics
  - Speed of intake
  - Smoothness
  - Laboriousness
- Et cetera…

Speech breathing across different speaking styles



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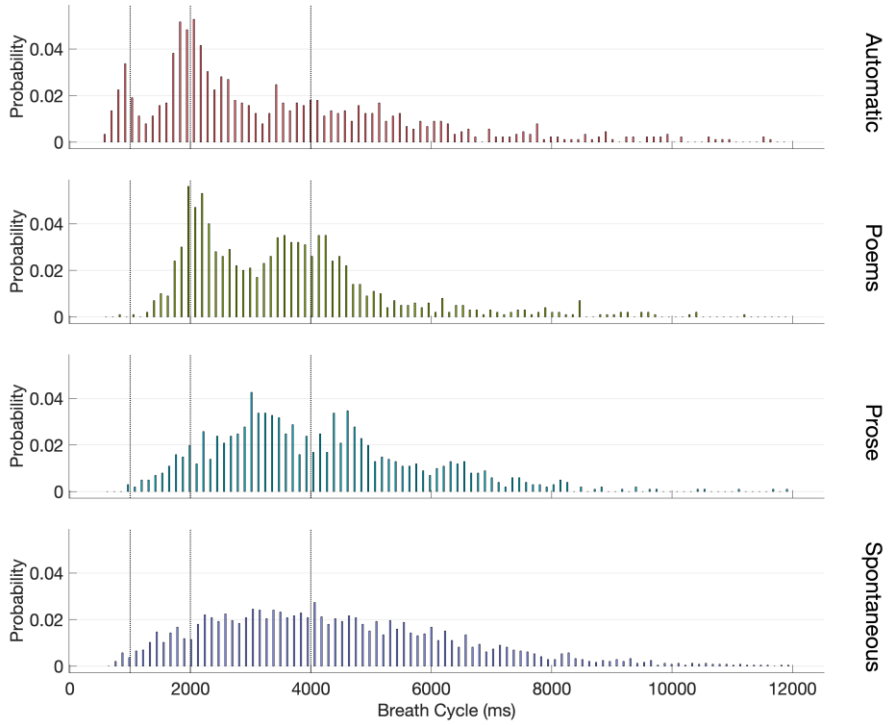
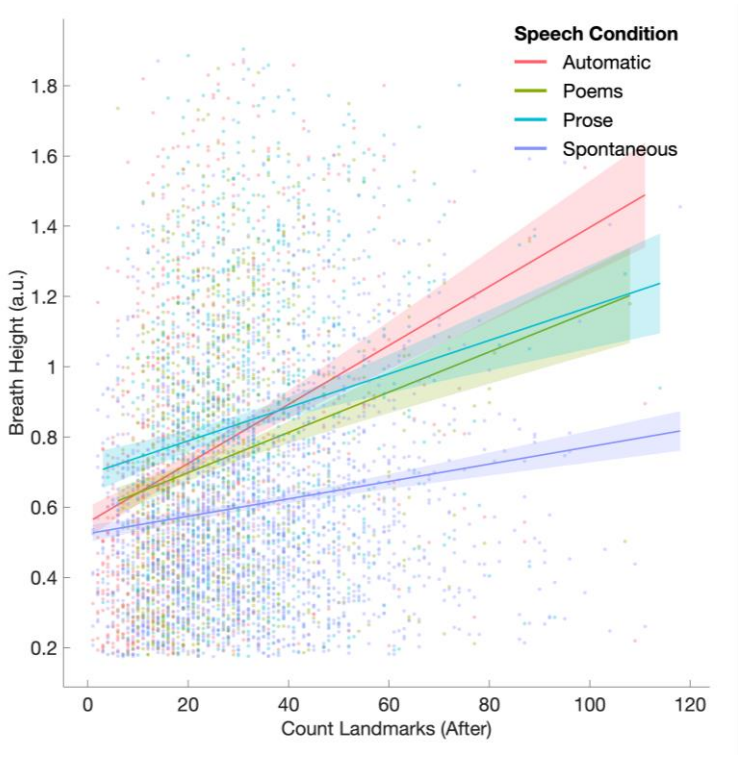
Examples of Applications

Speech and language

Distribution of
respiratory cycle duration



Breath size as a function of
subsequent utterance size



MacIntyre, 2022

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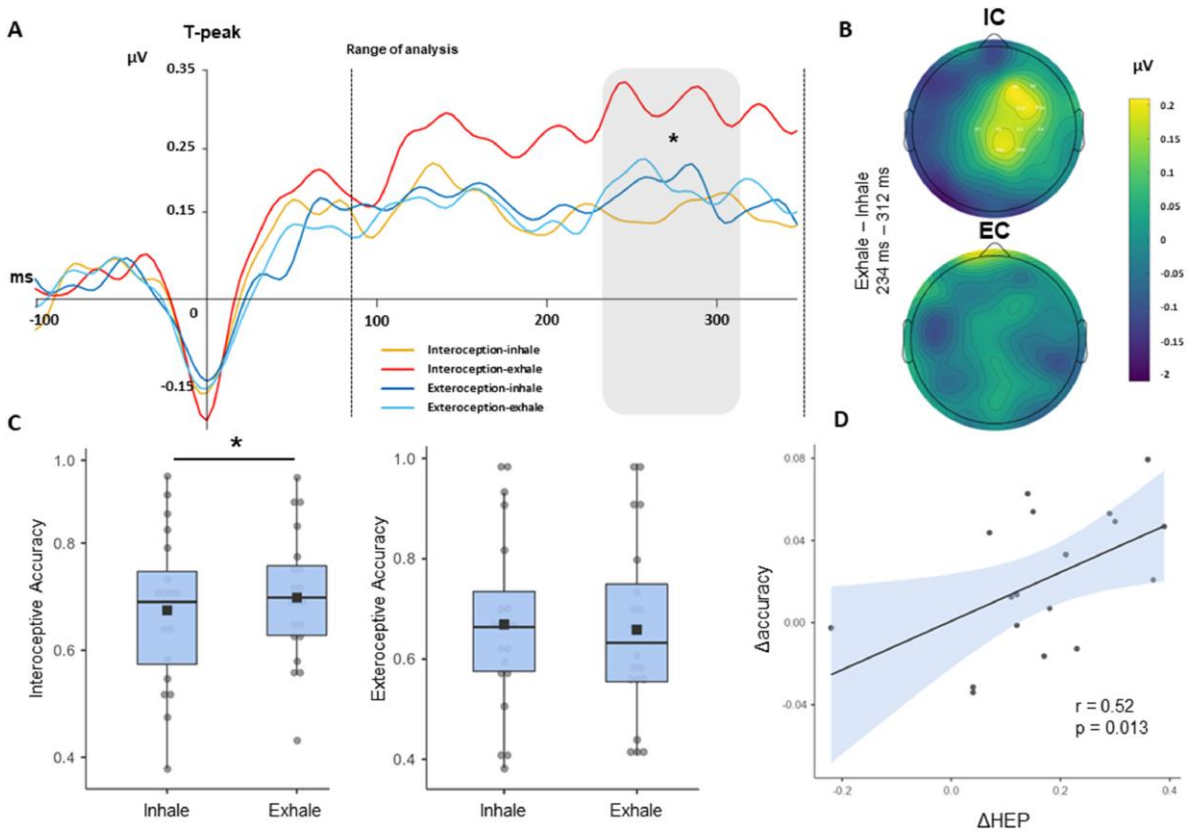
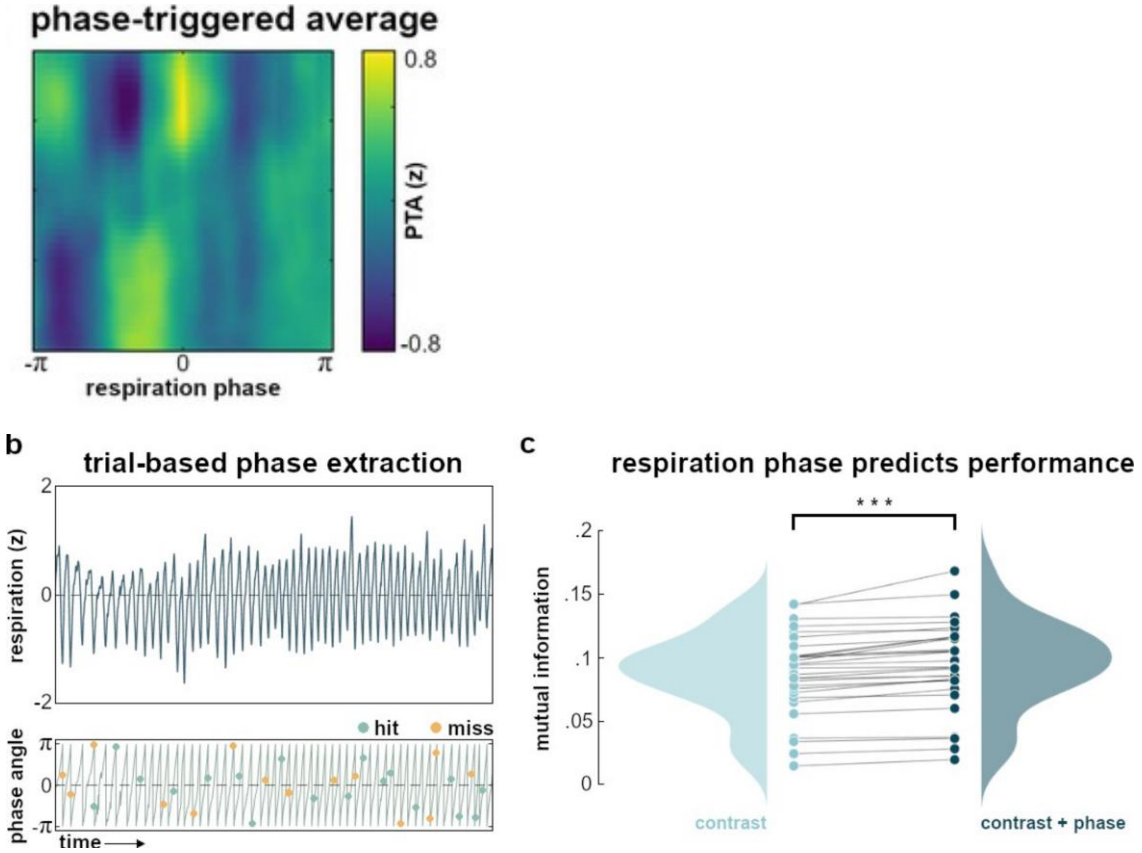
Interoception



- The heartbeat-evoked potential (HEP) is of a greater amplitude during exhalation, compared to inhalation
- When tapping to their own heartbeat, participants showed a stronger respiratory phase-dependent modulation of HEP and accuracy when attention was directed interoceptively.
  - HEP changes during interoceptive (but not externally directed) attention were positively correlated with higher detection accuracy at exhalation than inhalation.
  - Exhalation may allow attentional shift towards the internal bodily states?

Zaccaro et al., 2022

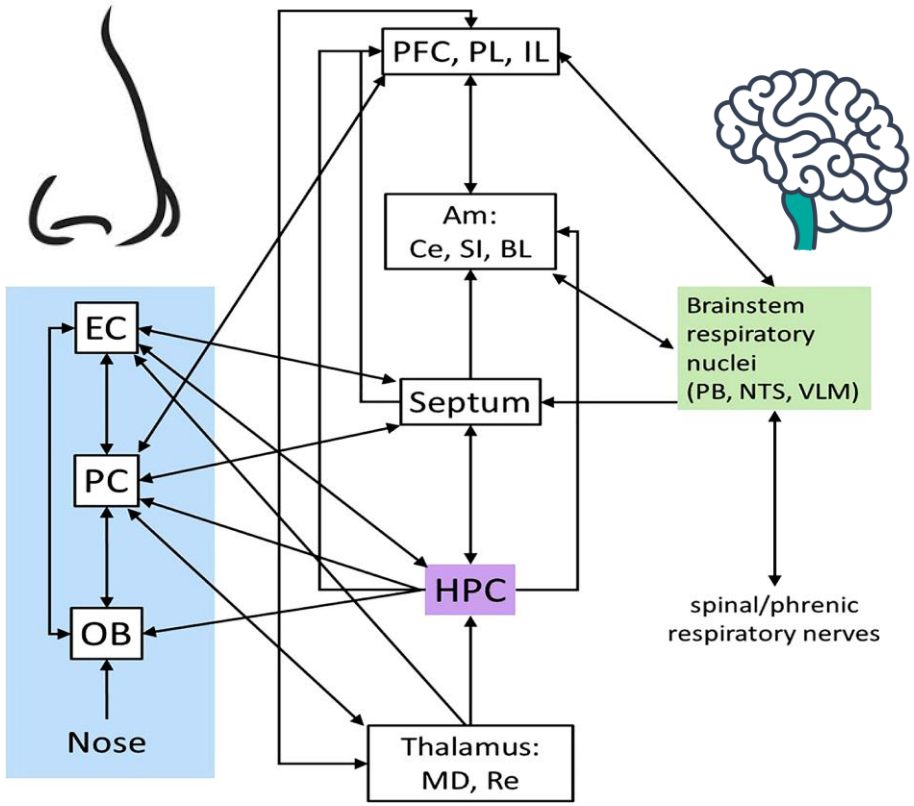
Perceptual sensitivity



- Compared parieto-occipital MEG power spectra for detected and undetected near-threshold visual targets
- Correlation between respiration phase and detection precision related to the suppression of alpha band power, which in turn is modulated by the phase of respiration.
- Significant respiratory modulation of cortical parieto-occipital alpha rhythms previously found to be related to perceptual performance.

Kluger et al., 2021

Learning and memory



J Neurophysiol 122: 563–571, 2019.
First published June 19, 2019; doi:10.1152/jn.00200.2019.

REVIEW | *Higher Neural Functions and Behavior*

The rhythm of memory: how breathing shapes memory function

Detlef H. Heck,[1] Robert Kozma,[2,3] and Leslie M. Kay[4]
[1]*Department of Anatomy and Neurobiology, University of Tennessee Health Science Center;* [2]*Department of Mathematical Sciences, University of Memphis, Memphis, Tennessee;* [3]*Department of Computer Sciences, University of Massachusetts Amherst, Massachusetts; and* [4]*Department of Psychology and Institute for Mind and Biology, The University of Chicago, Chicago, Illinois*

- Respiration affects oscillatory activity in key memory structures at frequencies implicated in memory function
- Task-based differences in human performance suggest nasal vs. mouth breathing may affect cognition/behaviour differently
  - Pathways through to neocortex via olfactory bulb, as well as brainstem
- “Breathing as a cortical organizing principle” across diverse regions and networks

Conclusion

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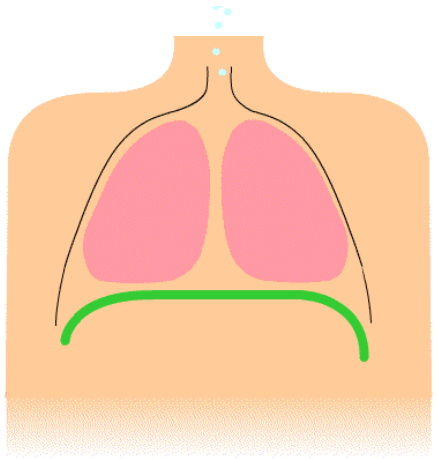
Summary

- Breathing encompasses more than maintaining basic homeostasis in humans
  - Speaking and coordinating socially
  - Interoception and self-regulation
  - Cognition, motor control, sensory perception
  - Global signal uniting disparate regions and networks?
- Breath belts provide a simple, cheap, and accessible tool for spirometry



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Questions?