An alternative technique for measuring respiratory motion in speech

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Motivation

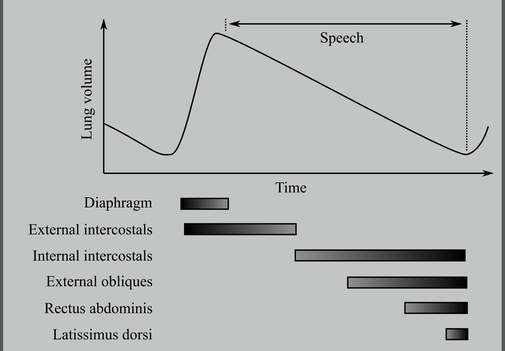
- Evaluate alternative to measure breathing-related movement during speech
- Standard: Respiratory Inductance Plethysmograph (RIP)
- Is triaxial accelerometry a useful replacement / supplement?

Background I: Respiratory monitoring:

- Triaxial accelerometers: Measurement of accelerations in three dimensions, regardless of device or subject orientation.
- Extraction of a one-dimensional respiratory signal by tracking the major axis of breathing and calculating rotational rates about this axis.
- Integration in order to extract respiratory rate mm/s)
- Previous Study - Monitoring Application [1]:
- Correlational Study: Rotational Rate of the abdomen can serve as proxy for respiratory airflow:
  → Almost perfect correlations of rot. rate with airflow measured by a nasal cannula connected to a pressure transducer (r=0.94).

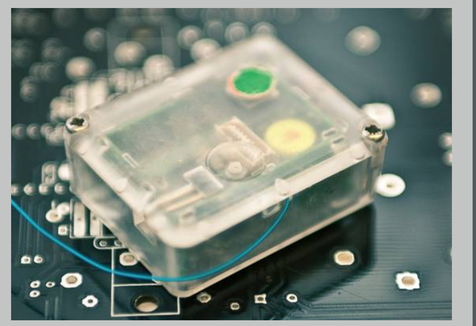
Background II: Speech Respiration

- Objective: Maintainance of (almost) constant subglottal pressure. Achieved by a complex interplay of expiratory and inspiratory muscles.
- First comprehensive approach: Edinburgh model and modifications [2, 3] and its remodelling [4].



Material & Method

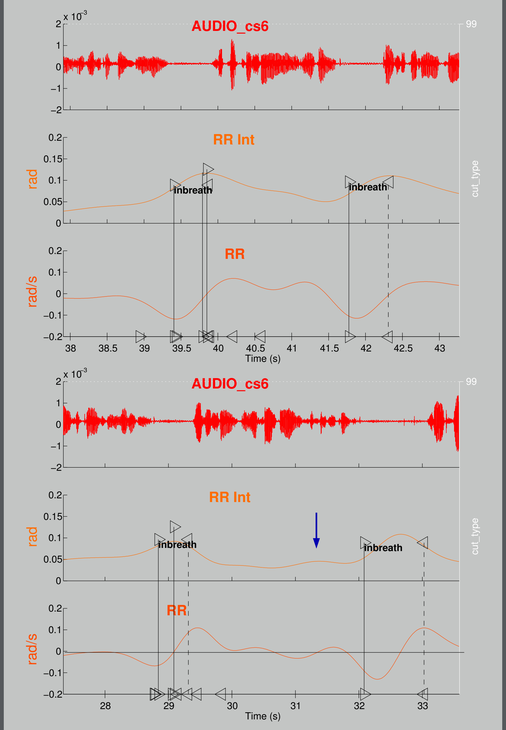
- Speech Breathing
  - Orient-3 wireless sensor device
  - Freescale MMA7260Q three-axis accelerometer
  - Location: lower costal margin, just below the ribs, attached using surgical tape.
  - This location usually gives the clearest rotation measurement
  - Accelerometer outputs on the device had 35Hz second order analog filters. Sample Rate = 128Hz.
  - normal breathing was taken during the same session.
  - Processing of accelerometer data following [1]



- Acoustic Waveform
  - 16-bit audio from a hypercardoid microphone, sr 32kHz.
  - Manual annotation by an expert annotator.
  - Annotation included periods in which there was audible inbreath.
- Synchronization
  - Parallel reording of speech movement using EMA.
  - The EMA SYBOX attention signal was used as a master clock
  - SYBOX clock ticks used as external trigger for Speck basestation device which controlled the sampling and transmission schedule of accelerometer data from wireless sensor.

Qualitative Analysis

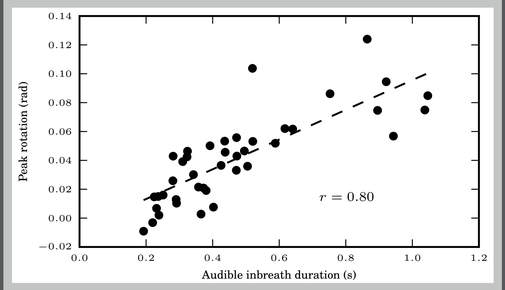
- Annotation: Handlabelled portions of audible acoustic inbreath.
- Top panels: Acoustic waveforms of representative utterances
- Bottom panels: Integrated rotational rates (RR Int)
  → hypothesized correlate of lung volume (RR Integ).
- Middle panels: Rotational rate (RR) of the breathing sensor.



- Results:
  - Automatic inbreath detection [1, 5] detected between 85 and 95% of the hand-annotated inbreaths (15 to 23% false positives).
  - Peaks in RR Int correspond to a location late in the acoustically audible in breath.
    → maximum lung volume corresponds to such a location. This suggests that timing of inbreaths can be extracted using an accelerometer.
  - BUT: Lung volume function would be expected to monotonically decrease over the course of an utterance.

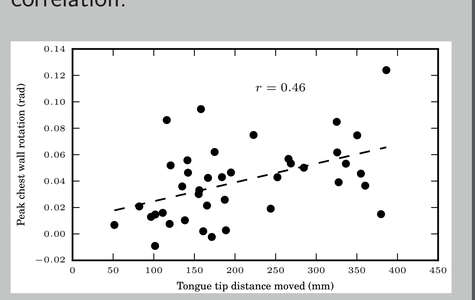
annotation vs. peak inspiration

- Correlation between duration of audible inbreath and peak height of the integrated signal.

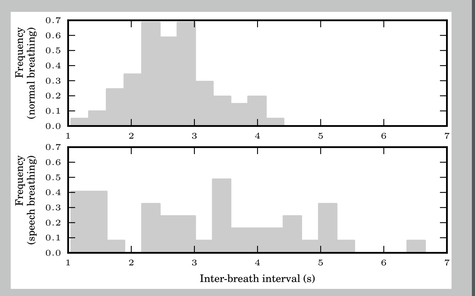


Replication of some key findings

- Inspiration Depth and Quantity of Speech have often been reported to be positively correlated [6].
  → Our data (from [5]): Weak positive correlation:



- Speech breathing is irregular.
  →Distribution of inter-breath intervals in normal and speech breathing as measured by our technique (see [5]):



Result Summary & Discussion

We have shown that accelerometer-based respiratory monitoring can be applied to speech breathing. We were able to replicate some of the most basic findings concerning speech respiration: Speech breathing is characterized by irregularity and reduced frequency in comparison to normal breathing. Further, the rotation maximum mostly coincides with audible inspiration and matches well with the place of expected maximum lung volume. However, the gradual decrease in lung volume over the course of the utterance is not perfectly reflected in the data.
The exact reasons for that remains unknown but provides guidance for future research: It would be worthwile applying several sensors measuring respiratory activation in parallel. For example, the accelerometers used here could also be supplemented with gyroscopes, measuring rotation directly. A further direction would be to carry out multi-method studies which using the combination of accelerometer/gyroscope with Respiratory Inductance Plethysmography (RIP).

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