An alternative technique for measuring respiratory motion in speech

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Introduction

The current contribution aims to measure breathing-related movement during speech using a technique deviating from Respiratory Inductance Plethysmography (RIP) which is most commonly used for that purpose. In this pilot study, we are making first attempts to validate the use of tri-axial acceleromaters in measuring movements associated with breathing. In the current study we use wireless sensor devices that tracks the axis of rotation and obtains angular rates of breathing motion (see Figure 1).

Previous research has already proven that accelerometers can be applied to respiratory phenomena: Bates et. al. (2010) have shown that the device worn on the abdomen is able to measure inclination changes due to breathing during sleep in monitoring situations. In particular, the analysis in Bates et. al. transforms the triaxial accelerations measured by a sensor attached to the abdomen into angular rates by extracting the principal rotational axis and integrating the obtained signal. Bates et. al. were able to show that in non-speech situations (in sleep), angular rate exhibits almost perfect correlations with measures of nasal flow obtained from a nasal cannula.

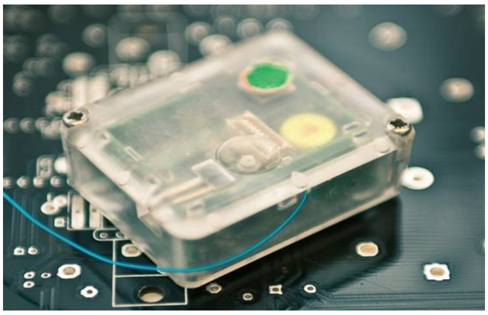

Figure 1: Hardware for the acquisition of breathing motion..

Method

In order to extend these finding to speech situations, we synchronized the accelerometer data with both Electromagnetic Articulography (AG500, Carstens Medizinelektronik) and the acoustic waveform by means of the AG500 SYBOX and dedicated synchronization hardware developed for that specific purpose. The synch signal as well as the acoustic waveform were captured by hardware manufactured by Articulate Instruments. For the purposes pursued here only the acoustic and the accelerometer data are of interest. Sampling rates were 32kHz for the audio signal and 128Hz accelerometer data. The accelerometer was attached to the abdomen/chest border of a healthy male speaker of British English with no known history of speech or hearing pathology. Pre-processing and the extraction of rotational rate followed procedures detailed in Bates et. al. 2010. The rotational rate (RR) signal was then integrated numerically, in order to obtain a hypothesized correlate of lung volume (RR Integ).

Speech material consisted of a read passage and dialogue tasks with an interlocutor recorded in an audio-only condition. The acoustic waveform was annotated using PRAAT, creating several levels of annotation in addition to the orthographic transcription. These include acoustic silence and audible in-breaths as well as a simplified version of ToBI. In addition to these acoustic markers, we determined several markers in the RR and RR Int signals associated with audible in-breaths (max. RR Int., max. RR during audible inspiration, distance travelled during inspiratory movement).

Results

The basic findings are illustrated in Figure 1. Both panels show audio data in the top panel, and RR Int and RR in the middle and bottom panels respectively. First of all, it can be shown that the peaks in RR Int correspond to a location late in the acoustically audible in breath. Assuming that the maximum lung volume corresponds to such a location, this is an encouraging finding as it suggests a basic validity of the measurement approach taken. Other findings put into question this physiological validity though: During expiration, one would expect the lung volume function to be monotonically decreasing. This is often the case, but unfortunately not always, cf. left and right panels in Figure 1. The left panel shows the expected steady decrease in the integrated signal while there are unexpected intermediate plateaus in the right panel. This secondary hump is marked by the blue arrow in the right panel.

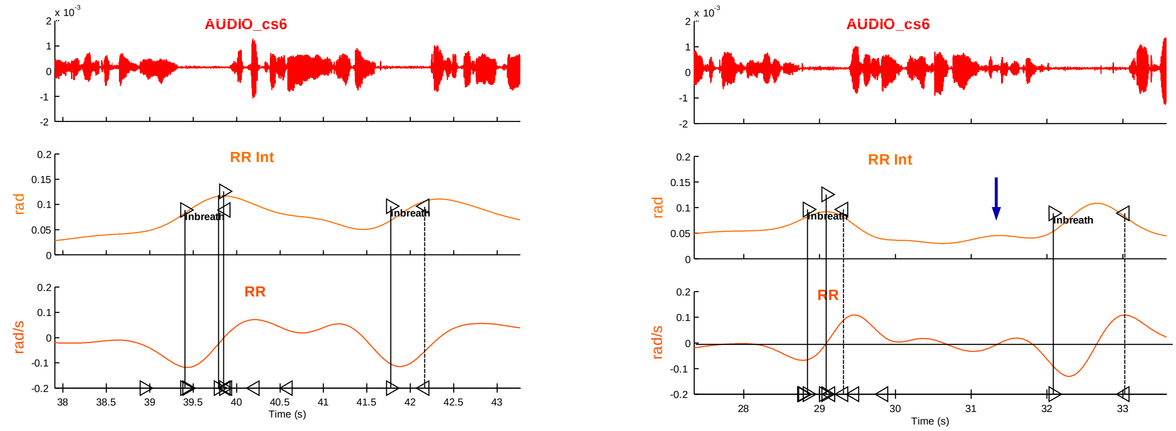

Figure 2: Example Data. The top panels show audio data, the middle panel the integrated rotational rate, and the bottom panel rotational rate. Landmarks shown include the audible in breath as well as maximal amplitude in RR Integ.

Summary and Outlook

Taken together, the use of tri-axial accelerometry has at least in part been successful. First of all, it can account for basic physiological findings: The point of maximal inspiration corresponds well with maxima in the amplitudes of the integrated rotational rate. Still, there are other aspects of the signal that currently cannot be explained, in particular the method fails to mimic the assumed monotonous decrease in lung volume. The origin of this pattern currently is unknown and needs further exploration.

For this purpose it would be relevant to to compare movement of the speckle on the lower rib cage/abdomen edge (current data) with the movements of two speckles attached separately to the abdomen and chest wall. The accelerometer data used here could also be supplemented with additional gyroscopes, i.e. devices that measure rotation directly.

A further perspective worth pursuing would be to carry out multi-method studies which could comprise the combination of accelerometer/gyroscope with alternative techniques for measuring respiratory activity. Calibrated Respiratory Inductance Plethysmography (RIP) has often been used in conjunction with measures of intraoral pressure in order to make estimates of lung volume – effectively converting the measured inductance from Volts to litres (e.g. Chadha et al. 1982). To explore whether such calibrations are also possible with the rotational parameters used in the present study could ultimately answer the question whether the method studied here can prove to be a valid tool for speech research on respiratory phenomena.

References

Bates, A., Ling, M. J., Mann, J. and D. K. Arvind (2010). Respiratory Rate And Flow Waveform Estimation From Tri-Axial Accelerometer Data. 2010 International Conference on Body Sensor Networks.

Chadha et al. (1982) "Validation of respiratory inductive plethysmography using different calibration procedures" , Am Rev Respir Dis 125, 644-649.