Estimation of sound pressure levels of speech from skin vibration of the neck

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Abstract

In situations when microphones are problematic or inconvenient to use, such as in measurement of speech in noisy environment, or in long-term monitoring of voice (voice accumulation/dosimetry), it can be advantageous to use a neck accelerometer for measurement of voice intensity. So far, it has not been very clear whether this can be done with an accuracy approaching the accuracy of microphone measurements. Therefore, the paper addresses the question: How accurately can sound pressure levels (SPLs) of speech be estimated from skin vibration of the neck?

Measurements using a miniature accelerometer (BU-7135 by Knowles Electronics) were carried out in 27 subjects (10 males and 17 females) who read Rainbow and Marvin Williams passages in soft, comfortable and loud voice while skin acceleration levels (SALs) and SPLs were simultaneously registered and analyzed every 30 ms. The accelerometer was attached to the skin of the neck at the jugular notch by means of a surgical adhesive (Mastisol®) and a suture strip

The results reveal that a) the skin acceleration levels generally correlate with sound pressure levels, i.e., increase in SPL is causing an increase in SAL (as indicated by the best fit relationship), but simultaneously b) there is considerable variability of the values around the best-fit relationship (Fig. 1). The variation around the best fit relationship limits the accuracy of the estimation of the immediate and peak SPLs

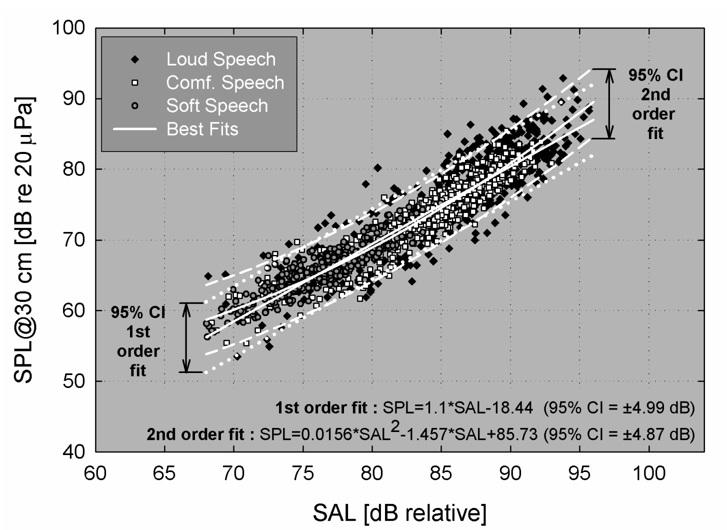

Fig.1: The relationship between the skin acceleration levels (*SAL*) and sound pressure levels (*SPL*) obtained from the combined soft (gray circles), comfortable (white squares) and loud (black rectangles) readings of the Rainbow passage. The solid white lines show the 1st order (linear) and 2nd order (quadratic) best fits of the data, the dotted and dashed white lines mark the 95 % confidence intervals for the linear and the quadratic fits, respectively.

to, on average, about ±6 dB in males and ±5 dB in females (when expressed by the 95% confidence interval), the overall range being between ±2.5 and ±8.5 dB in the best and worst subject cases, respectively. Similar accuracy was found for the Rainbow as well as the Marvin Williams reading passages.

The estimation of the long-term average SPL of speech from the skin vibration was found much more accurate than the immediate SPL values, however (Fig.2), as the different speech sounds and transients average out. The mean SPLs of speech were possible to estimate with the accuracy better than ±2.8 dB (95% confidence interval) when the subjects were individually calibrated and the individual best fit SPL/SAL relationship was used for the SPL estimation. This accuracy is comparable to the accuracy of traditional SPL measurement with a sound level meter placed at 30 cm distance and it makes the accelerometer an interesting sensor for SPL measurement of speech when microphones are problematic to use.

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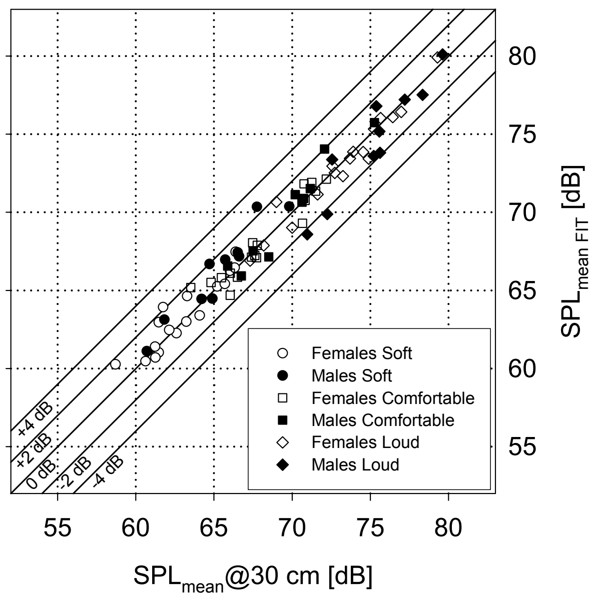

Fig.2: The relationship between the mean *SPL* of speech (SPL_{mean}) and the mean *SPL* estimated from the accelerometer signal by means the 2nd order best fit ($SPL_{meanFIT}$). Values for soft, comfortable and loud speech by 10 male and 17 female subjects are shown in the plot. The solid lines mark equality and under- and overestimates in 2dB intervals. The data show that the accuracy of the estimation of the mean *SPL* of speech is better than 3 dB for all the cases.