Is there an otoacoustic fingerprint?

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Abstract: This study examines the notion of fingerprint like properties of otoacoustic emissions (OAE) and their consequential biometric potential. To do this, transient-evoked otoacoustic emissions (TEOAE) of 10 subjects were recorded over a period of 7 days. A subset of these measurements was used to train an artificial neural network. The trained network was then used to identify the same subjects on the basis of a second subset of TEOAE measurements. All 10 subjects were identified with a 100 % success rate. This successful biometric application of TEOAE supports the idea of the otoacoustic fingerprint.

1 Introduction

Since the discovery of otoacoustic emissions (OAE) almost 30 years ago, they have become an integral part of audiometric practice and hearing research. Otoacoustic emissions are a by-product of the cochlear amplifier and can therefore be used as an indicator for inner ear functionality. “Both experimental and theoretical arguments have led to a consensus that the cochlear amplifier is attributable to the generation of force by outer hair cells during excitation to oppose the viscous damping of the cochlear partition.” [3]. This generation of force causes a weak travelling wave to run back to the vestibular window and to be transmitted by the auditory ossicles to the tympanic membrane from which it is emitted into the ear canal.

When reading up on OAE, one can find observations and remarks about a degree of stability [5,12] and uniqueness [4,11] about individual OAEs. These impressions are often summarized using the term otoacoustic fingerprint. By alluding to the prototypical biometric measurements - the dactyloscopic fingerprint - it is implied that otoacoustic emissions can be used to reliably identify individuals. In the past, an analogous term, namely the *voiceprint*, made a similar allusion. It refers to visual pattern comparisons of short termed spectrograms to assess if utterances were produced by the same speaker [7]. This technique did not stand up to scientific scrutiny [2] and is rejected by the community of forensic phoneticians [6].

Consequently, it seems prudent to investigate if the otoacoustic fingerprint can live up to its name and provide means to successfully identify individuals. Swabey et al. have published several studies that statistically support the notion of the individuality of otoacoustic emissions [8,9]. An actual attempt to use this phenomenon to identify individuals has not been made though. The following experiment was designed to attempt just that.

2 Procedure

2.1 OAE Measurements

The OAE measurement procedure most suited for biometric application is using transient-evoked otoacoustic emissions (TEOAE). A broadband click of 0.4ms duration and 80dB intensity is projected into the ear to stimulate the cochlea along its entire length. The resulting response of all outer hair cells is then recorded. Due to frequency depended run-time differences, the high frequency components arrive back earlier than the low frequency components.

One OAE measurement consists of 2080 successful stimulus response cycles. This procedure is applied to compensate for the very low intensity (0.5 mPA) and briefness (10ms) of the outer hair cell response, which can easily be superimposed by ambient noise (e.g. clothes rustling) or bodily sounds like rushing blood or noisy breathing. To further increase reliability, OAE measurements are stored in two alternating buffers for further comparison and calculations. The three time signals in figure 1 show the means of both buffers (A and B) as well as (A+B)/2 and (A-B)/2.

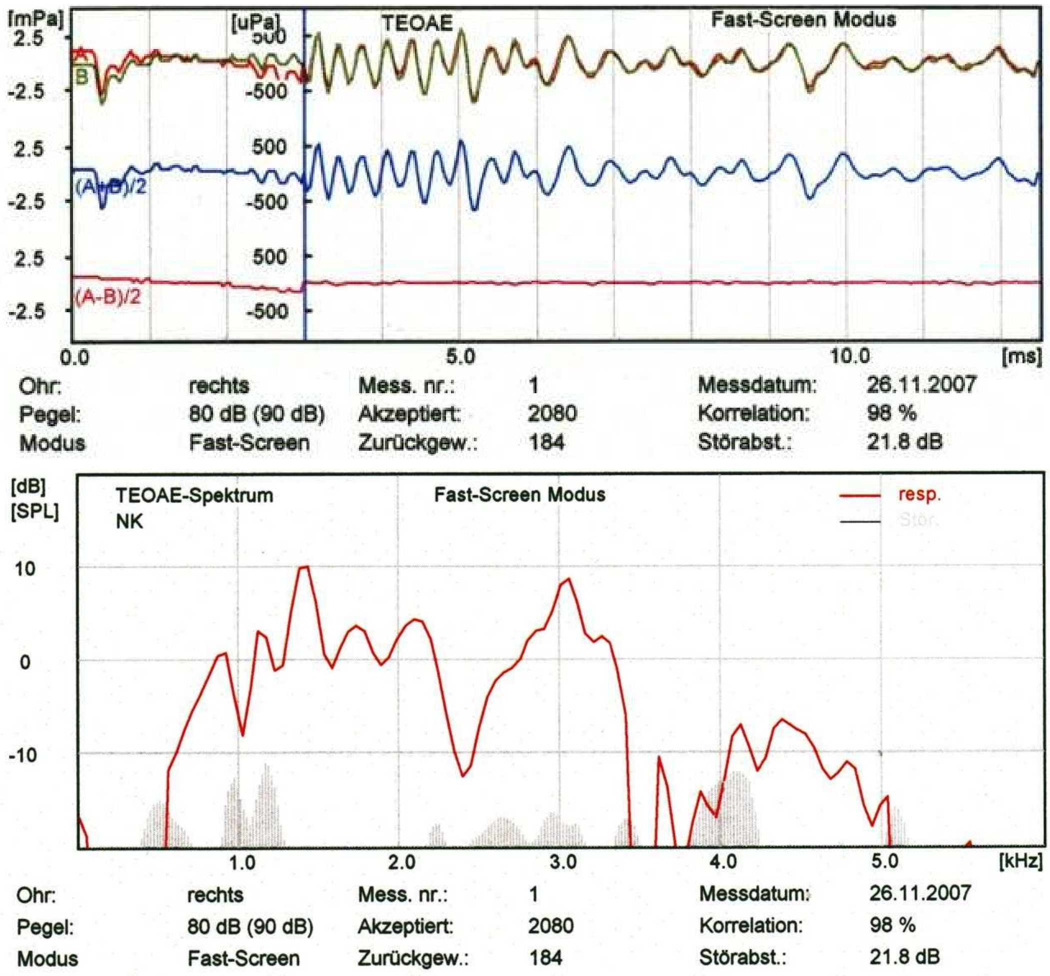

Figure 1 - TEOAE time signal (top) and spectrum (bottom)

For this experiment, all TEOAE measurements were taken at the otolaryngeal department of the *Klinikum Mutterhaus der Borromäerinnen* in Trier, using the *Madsen Capella* system by *GNotometrics* and a standard TEOAE probe.

Transient-evoked otoacoustic emissions of 10 individual's right ears were recorded in two sessions with a 7-day interval. Each time a set of 12 measurements were recorded totalling in 24 per individual. The 10 test subjects (7 female, 3 male) were between 20-29 years old, the average age being 25.07. None of the test subjects had any hearing impairment or other relevant illness at the time. Only the time signal (A+B)/2 was used in the subsequent steps of this experiment.

2.2 Neural Network

Artificial neural networks mimic biological neural structures and abstract the process of mental learning. Prior knowledge about distinctive signal parameters is not required but will be defined by processing training samples. Therefore, one major application of artificial neural networks is pattern recognition and classification. For further information about neural networks see [8].

The neural network used in this experiment was a simple single layer perceptron network set up with the *Neuropro* application on *Medav's MOSSIP 3000*. In this network each subject (S1-S10) is represented by a separate class (c1-c10). 20 of the 24 individual OAE measurements were added to the corresponding class as training samples in order to manifest an OAE 'profile'. Due to the closed set conditions, the neural network featured no rejection class.

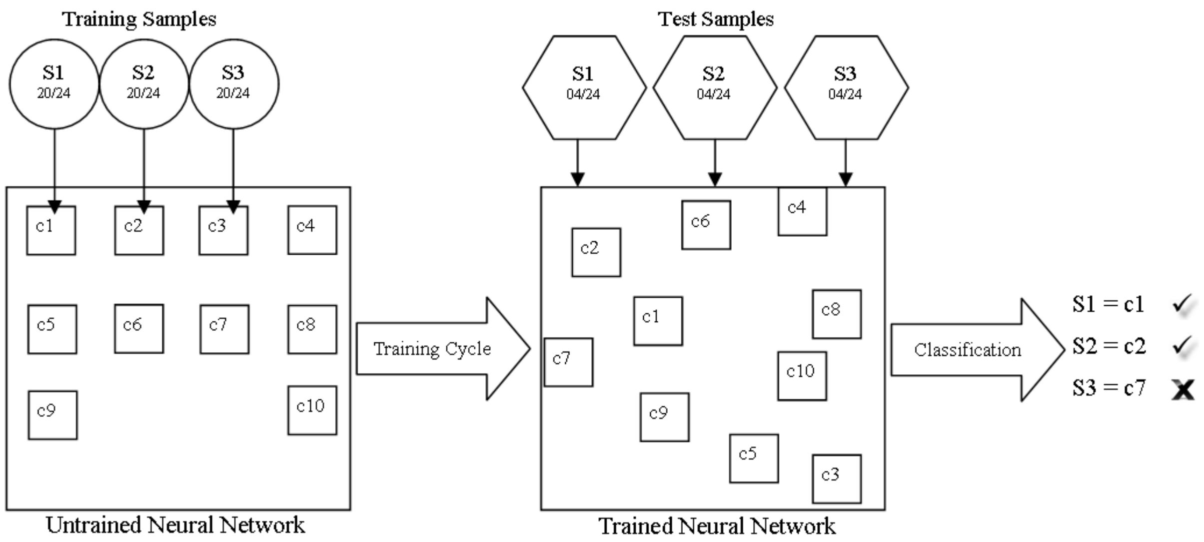

Figure 2 - Neural Network

After completion of the training cycle, all remaining samples (4 per individual) were presented to the network in order to be classified and assigned to one of the test subjects. The systems classification results were recorded and manually checked against the actual sample ID.

3 Results

All ten individuals where identified with a 100% success rate. No false hits occurred. The procedure (training and classification) was repeated twice with the same result.

4 Conclusion

The present experiment shows that reliable identification using TEOAE is possible. Inter-individual variance was distinct enough for the neural network to establish a unique otoacoustic fingerprint for each of the ten individuals. Over the course of 7 days the intra-individual stability was strong enough not to cause significant interference.

Of course the number of test subjects as well as the time frame in this experiment was rather limited. The flawless identification performance on the other hand would suggest that an increase in both parameters might still provide descent results. This expectancy is supported by Swabey et al. [10], who statistically confirmed stability of individual OAE for at least 6 months. The same study confirms that the time signal is sufficient for a high-level classification performance even with larger test populations (760 and 561 subjects).

Even if OAE continue to prove biometric potential, a "real world" biometric application of the otoacoustic fingerprint would still be pending technological advances to compensate for the vulnerability of the short and weak signal.

5 Acknowledgment

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