The melody of crying

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Summary   As the speech of a normal hearing and a deaf person are different, author expects differences between the crying sound of normal hearing and hard-of-hearing infants as well. In this study the author determined by computerized algorithms the melody of 2762 crying sounds from 316 infants, and compared the results between infants with hearing disorders and normal hearing. The analysis of the crying sounds is aimed to work out a new, cheaper hearing screening method, which would give a new potential to the early detection of hearing disorders. All the applied steps were developed by automatic, computer-executed methods providing reproducible, objective results in contradistinction to some previous studies, which had applied manual methods and reached subjective results.

Several possible ways for digital signal processing of the infant cry are discussed. A novel melody shape classification system was created to obtain a more precise distribution of the melodies by their shapes. The system determined 77 different categories, where the first 20 categories covered the 95% of the melodies. The applied methods were created and tested in a huge number of melodies.

1. Introduction

1.1. Hearing screening today

Nowadays numerous Universal Newborn Hearing Screening (UNHS) programs are running in several countries around the world with an increasing success and efficiency [1]. By these programs the average date of detecting hearing disorders (and starting intervention) has decreased to the first few months of life (it was typically a few years). Hard-of-hearing infants, therefore, have better chance for an adequate mental, physical, physiological, social, and language development.

The great majority of the UNHS programs apply objective audiometry (as various OAE or BERA techniques), and use a multiple-stage strategy to increase the efficiency.

At the Newborn Hearing Screening (NHS) 2006 Conference (Cernobbio, Italy, June 1—3), in the keynote lecture from Bolajoko O. Olusanya and in several other reports as well the following recommendations and ideas were presented [2]:

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- developing countries many a time cannot put up the money for starting a UNHS program (costs of equipments) or for carrying on the program (costs of explorations and servicing) and
- for more acceptable UNHS programs cheaper hearing screening methods should be developed.

Although the existing strategies of objective audiometry have a high reliability, the author's research team finds it essential to try to work out a new, cheaper screening method, which would give a new potential to the early detection of hearing disorders. This research team is aimed to create a new hearing screening method which tests the sound of the infant cry.

Existing screening methods test some parts of the whole auditory system, e.g. OAE checks if the hearing system functions or not between the outer ear and the inner ear. During sound production the whole auditory system is involved to control the quality of the produced sound, in this way the acoustic analysis of the produced sound (as crying) might be used to check the function of the whole auditory system.

1.2. The information of sounds

After birth, the first obvious sign of life is crying. This is the first mean of communication; experienced mothers (as well as nurses) can translate the crying sound and understand the needs of their own babies. There are typical, common attributes of crying as well as individual ones: all of the crying sounds seem to be similar, but a mother can distinguish the crying sound of her own baby from the sounds from other infants.

During crying, the volume, the pitch and the tone color is changing. The changing of the pitch is called *melody*. Based on the experiments so far the author declares that the melody curve of crying, except sudden pitch shifts, is continuous.

In human life, the melody of speaking is essential to express the mood, intention, etc. During infancy, the most typical sound is crying. The melody of crying also gives information about the physical, physiological state of the infant: it is characteristic for typical states as pain, hunger, discomfort, boredom, etc. [2−12].

The state of health can modify the produced sound as well. People have a typical voice if they have a cold, if they suffer from pharyngo-laryngitis, or even if they have impaired hearing. A normal hearing person can control his produced sound, while a deaf person cannot. Thus it can be determined from the sound of speaking if the patient has problems with the hearing or not. By this

conception, different produced sound is expected between normal hearing and hearing impaired infants, whose produced sound is crying.

In 1982 Hirschberg and Szende collected over 100 sound phenomena from infants suffering form several diseases [13]. They reported about extremely high-pitched melodies (around 1000−2000 Hz) of crying at hard-of-hearings contrary to the healthy infants' mean frequency range around 400−500 Hz. In 1995 Cacace et al. tested several parameters of the crying of normal hearing pre-term and healthy normal-term infants [14]. They found connections between age, weight and some acoustic features of the crying. In a study of Schönweiler et al. the auditory feedback was tested [15]. With a digital audio tape (DAT) recorder a real-time amplified feedback of the crying was driven to a headphone on the infant. When this feedback was suddenly delayed, infants with hearing disorders kept crying while the healthy ones got confused. In 1999 Möller and Schönweiler analyzed infant cries for the early detection of hearing impairment [16]. They applied self-organizing topological feature maps to compare the Mel frequency cepstral coefficients between healthy and hearing impaired infants and obtained a classification accuracy of about 75%.

It can be declared that even now there is no method with high efficiency which can conclude on the state of hearing disorders from the crying sound. The author's aim is to create algorithms which calculate parameters of crying and diagnose hard-of-hearing from them with a better efficiency than the above-mentioned methods had. After several studies dealing with other attributes of crying [17−21], the author turns to the analysis of the melody of crying with the same purpose.

2. Subjects and methods

2.1. Subjects

For this study data from 316 infants were collected. Most of the recordings were made in several hospitals in Hungary and furthers at home. There were 147 boys and 169 girls with a mean age at 189.82 days. As approximately 0.2−0.3% of the infants born with hearing loss [22], only 23 of the 316 infants had medium grade hearing loss or deafness (threshold of hearing under −40 dB). The grade of the hearing loss was diagnosed by objective audiometry (as OAE and BERA). The more important details about the infants involved are tabulated in the following table (Table 1).

It is worthy of note that the average age of the hearing impaired infants is higher than the normal