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ANALYSIS OF CRIES OF SINGLETONS AND TWINS DURING THE FIRST YEAR OF LIFE

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Abstract
The approach of our cry investigations is explained on the background of long-term analysis in singletons and twins. The focus is set on analyses of the fundamental frequency and its variations in time. Time variations of the fundamental frequency on different time scales are characterised with concern to their importance for the description of developmental stages. Behind a high variability of most cry features a universal program for prespeech development is hypothesised.

Introduction

For many years paediatricians have been searching for non-invasive tools to measure brain function of infants. Meanwhile there is growing evidence, that signal analysis of cries and non-cry vocalisations might be such a tool in future. The analysis of cries in their ontogenetic development might offer possibilities to assess vocal neuro-muscular maturation or to diagnose brain dysfunction ("cry-diagnosis"). Cry analysis might also provide understanding disturbances in speech acquisition in the light of developmental biology. Within the first months of life anatomical and functional maturation steps are reflected in changing cry features. Crying represents the first stage of speech acquisition [1, 2, 3, 4].

Two aspects of cry research, cry-diagnosis and tracking of prespeech acquisition, are strongly related and both fields require a suitable data base of normative cry data. In spite of intensive cry analysis over the last 30 years such a data base is not yet available. One reason is the lack of standards for cry analysis, generally accepted by the community of cry investigators.

In order to obtain reliable and reproducible results an essential precondition is a standardisation of data acquisition (better homogenisation of subjects, choice of highly standardised environments and recording conditions). But the most interfering obstacle for cry-analysis consists in the fact, that infant sounds exhibit a very high intra- and interindividual variability in many signal parameters. Even under strongly defined social and physical conditions an infant produces a variety of cry types characterised by a high variability in most acoustical parameters. Cry series of different children, recorded under "natural" conditions in a hospital, show such a high degree of variability that cry-diagnosis is almost impossible. So, a rigorous reduction of variability is essential.

Moreover, longitudinal investigations of individual children are necessary to track changes of variability structure as well as variability ranges for selected cry parameters during development. Such investigations require recording intervals, which are frequent enough to detect developmental regression phases [5]. Such phases interfere the monotonous improvement of vocalisation development. The transition between two stages of development is often connected with (so called) regression-phenomena: formerly well-trained elements suddenly (temporarily) disappear. According to our opinion this kind of regression is not a disintegration or a simple come back to primitive functional states, but a necessary latency phase for the installation of new functions. This is not a regression in the strict sense of the wórd, but it is more like a creative break [1,2,3]. These meanwhile well-known phases, which occur repeatedly during normal child development have to be taken into account to define normative data.

Approach

Crying is in comparison to speech a rather simple vocalisation. The upper vocal tract of infants is still immature in the first months, cries are mainly controlled by laryngeal activity. But why do we observe such a high degree of variability in cry features?

To begin with, we are confronted with innate individual differences of anatomical structures for sound production as well as of functional differences in sound control. Until now there exist no systematic investigations of the influence of these innate differences on commonly used cry parameters (our twin analysis might represent a first step in this direction). Next, differences in the maturation of the vocal-auditive system and the stepwise involvement of auditory feedback mechanisms in cry production generate additional variability. Hence, should one give up to follow the idea of cry diagnosis? A good strategy to answer this question is to analyse the variability of cry parameters in monozygotic twins.

In our work with twins we got the conviction, that this conspicuous variability is only masking innate universals of prespeech development. It is very likely, that innate developmental programs do not only exist in language acquisition, but also in prespeech acquisition. Analogously to Steven Pinker's "Language Instinct" we could call this "Prespeech Instinct" [6]. More and first of all well standardised cry studies will help to bring more light in this dark inheritance and finally will make cry-diagnosis successful.

Methodology

In a first step we focused our interest on the fundamental frequency (F0) of cries and its time variations, in order to cope with the high variability of cry parameters. The importance of the fundamental frequency is not only justified by the dominance of laryngeal processes in early sound production. The importance of F0 is further substantiated by the role of pitch for early perceptive processes and by the phylogenetic co-evolutionary history of sound production and perception [7,8]. The role of frequency modulations during the evolution of social communication explains also, why voice production is coupled with the smallest time constants of brainstem functions.

Having all these aspects in mind it is obvious, that simple measures like the average values of the fundamental frequency of a cry signal or its maxima and minima are not appropriate indicators for a neuro-developmental assessment of infants. Rather a set of parameters reflecting fundamental frequency variability on different time scales might be suitable.

Time variations of the fundamental frequency include fast frequency modulations (e.g. physiological tremor of laryngeal muscles, air turbulence etc.), slower frequency modulations produced by the control circuits of the F0 tuning mechanisms and very slow frequency modulations as part of intonation structures and cry prosody. Our long-term investigations show that intonation structures are especially important for the assessment of obtained stages of prespeech development of an infant. Further more they can also reflect stagnation of prespeech development in cases of severe brain disorders. This is exemplified comparing melody contours in normally developed children and children with severe neuromuscular retardation:

We found that the sequence of stages of prespeech development are good examples for the evolutionary principle of modular composition of complexity and the principle of repetition and specialisation [1, 2, 3, 4]. One of the first modules (building bricks) of prespeech development is a simple intonation structure, a rising-falling cry melody (Fig. 1a,b).

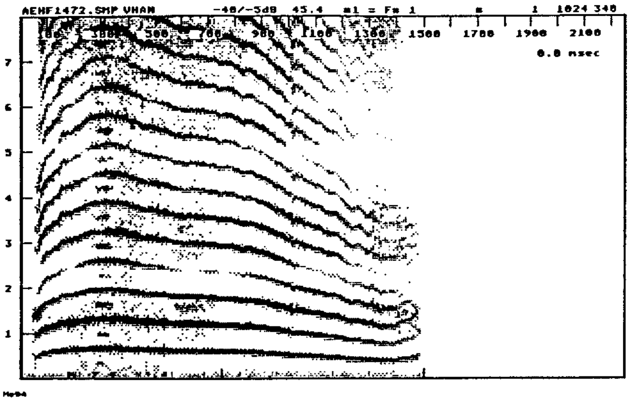


Figure 1a. Spectrogram of a spontaneous cry of a term born healthy infant at the 3rd day of life. The cry has a rising-falling melody, typical for this age. [3]

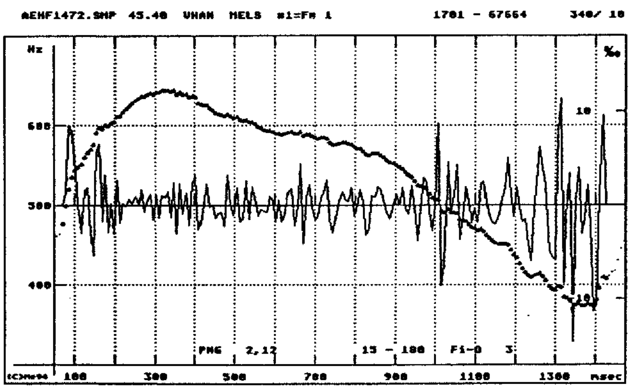


Figure 1b. Melody (dark line) and its perturbation-residuals of the cry presented in Fig. 1a. The rising-falling melody pattern is obvious. [3]

Further differentiation of cries often happens by a combination of this simple rising-falling intonation pattern to pattern sequences created by a simple repetition or concatenation of early patterns. In the simplest case this happens in form of a pattern-doubling (two rising-falling arcs) (Fig. 2), at later ages as a multiple repetition (Fig. 3). The creation of more and more complex cry sounds in the described way means also to develop, stabilise and provide building blocks essential for later speech acquisition. We have been testing these hypothesised universals of prespeech development in twins, also.

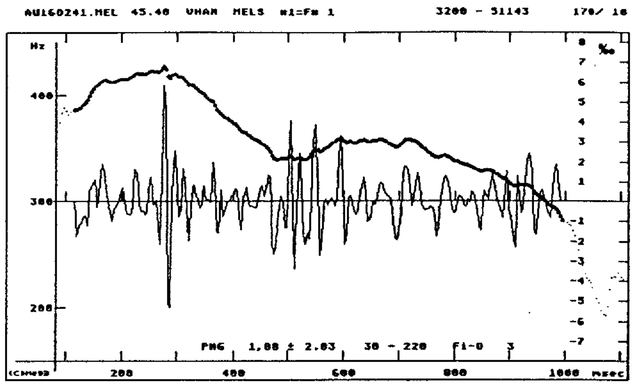


Figure 2. Melody (dark line) and its perturbation-residuals of a cry of an infant at the age of 7 weeks. The rising-falling melody pattern is now doubled. [3]

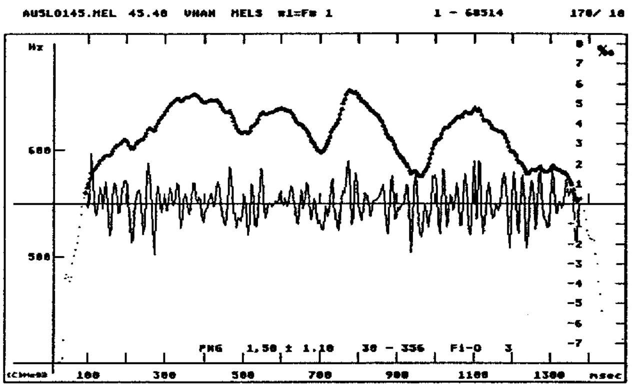
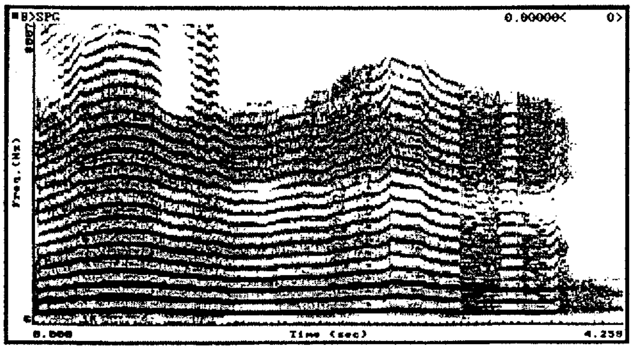


Figure 3. Melody (dark line) and its perturbation-residuals of a cry of the same infant of Fig.2 at the age of 23 weeks. The rising-falling melody pattern as a common "gestalt" consists now of four single rising-falling arches.[3]

For a better group homogenisation on the background of the above-mentioned problem of high variability in infant voice features we focused our investigations to twins. Subjects were 15 identical and 15 fraternal healthy twin pairs (classified by DNA-Fingerprint methods), whose spontaneous utterances were recorded over the first year of life. The analysis were done using a CSL-Model of Kay Elemetrics.

Here, we found a surprisingly high parallelism in monozygotic twins concerning the onset and manifestation of above-mentioned developmental stages [4, 9]. We cannot yet assess the part attributed to interindividual tuning mechanisms simply caused by twinship and the genetic part in the observed high synchronism in monozygotic twins. Nevertheless, the lower degree of synchronism in our dizygotic twins supports the idea of universality and innate determination of the described prespeech development.

Further support for the theory of modular composition of prespeech is provided by sound analysis of mentally retarded children. We will explain one case selected from a study of children suffering of West Syndrome [10]. West syndrome is an encephalopathy of early infancy with unknown pathogenesis. Riikonen et al. [11] describe a low nerve growth factor in patients with symptomatic infantile spasms which possibly reflects massive neuronal death. West syndrome comprises infantile spasms, abnormal EEG pattern with hypsarrhythmia and is often leading to severe developmental retardation [12-14]. Here we present a cry sonagram of a 3-years-old boy suffering from West Syndrome (Fig. 4). The boy is psychomotoric retarded, he does not speak. We analyzed the recorded spontaneous utterances using sonagrams (CSL-System,Kay Elemetrics) in order to describe the stage at which the child developmentally stagnated. As can be seen in Figure 4, the boy utters sounds consisting of two rising-falling arches. This double-arch melody pattern we described as the second stage of prespeech development in healthy infants at about 2 months (compare Fig. 2). A difference compared to a typical double-arch patterns in infant's cries is the duration of the utterance. In the represented sonagram we have a sound duration of 4.3 seconds, which is almost twice the value of healthy young infant's cries. Due to clinical records first fever seizures were observed in the boy at the age of 4.5 months. The double-arch melody pattern of his utterances might reflect a stagnation of his vocal development at the age of first manifestation of the brain disorder.



Some final remarks concerning the other, faster time variations of the F0: These frequency modulations might be more important for a detection of fine neuromuscular disorders. Dysfunction of neuromuscular mechanisms causes disturbances of the laryngeal co-ordination. These disturbances generate either fluctuations of F0 or the absence of finer "intended" modulations (rigid melody). Irregularities which are caused by neuromuscular disturbances are proposed to be slower and proposed to contain more regularity than for instance stochastic disturbances of air flow [1, 15]. In the case of mild brain disorders in singletons we observed a higher microvariability of F0. In the case of severe brain disorders (e.g. cerebral palsy, West Syndrome) the F0 contours of the cries are monotonous and reflect a loss of microvariability (rigidity).
For the sake of elimination of "intended" melody variations (as intonation or prosody) we investigated special frequency modulation bands not containing slow melody variations and very fast modulations (f-mod noise). These modulation frequencies were eliminated to get fine changes of F0 in time (microvariability). The filter output is integrated over time to provide a special calibrated perturbation index (PQ) (see Figures 1b, 2, 3). Filterings were done with spectral and/or other digital filters. Presented are cry melodies together with the time ordered function of perturbation of F0 (measured in promille) of singletons and twins. We used the signal analysis program "Time-Spectra", which was developed by W. Mende, for these types of analysis. Monozygotic twins have the same microvariability range at certain developmental stages and exhibit some features in sound spectra with a remarkable synchronism [4, 9].

Figure 4:. Sonagram (KAY Elemetrics) of a spontaneous cry of 3-years-old boy suffering from West Syndrome. The cry has a rising-falling double-arch melody, typical for healthy young infants at the second stage of prespeech development. The duration is almost twice as long as comparable sounds of infants. The cry features reflect a retardation of this boy.

CONCLUSION

Our results suggest a fairly good reproducibility of certain cry features of individual children. But often a lot of influencing factors and mechanisms mask these "innate cry features". The final objective of the twin studies is to compare the degree of synchronism of maturation processes between monozygotic and dizygotic twins in order to estimate innate components in prespeech development. The twin studies are also intended to promote progress in the framework of cry diagnosis.

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