ANALYSIS OF PRE-LINGUAL SOUND UTTERANCES OF CHILDREN IN THE FIRST YEAR OF THEIR LIVES USING THE LPC METHOD OF FORMANT EXTRACTION

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ABSTRACT - Sound utterances made by two children in the first year of their lives were investigated. The focus was on formant extraction using the Linear prediction analysis in combination with the FFT-spectrum. There is reason to assume that articulatory and therefore neurophysiological processes are predominantly represented in the 1st format while higher formants reflect anatomical and morphological changes during this particular period of ontogenesis.

INTRODUCTION

Language as a phenomenon of human communication continues to confront us with unanswered questions, especially as regards its genesis in evolution and ontogenesis. The progress made in the development of analytical techniques helps to increasingly perform detailed investigations of parameters involved in the formation of language, but also as early as in the cries of newborn's. Concerning the prelingual period preceding the individual acquisition of speech of everybody , most analyses so far to a great extend were based upon the cries of newborns. The intention of such investigations was to improve the knowledge of the role of different infant cry sounds as well as to find a possibility of using them for diagnostic purposes. The infant cry sound may be regarded an indicator for neurophysiological functions (Lester, 1984).

The study of human prelingual sound utterances, presented here, intensively includes the ontogenetic aspect. The centre of interest was a parameter which so far has hardly been examinded for this period: the formants. These represent the most important spectral characteristics in the acoustical analysis of speech. But this kind of resonance frequencies is also contained and determinable in the infant cry sound and in any non-lingual sound utterance too.

Our considerations proceeded from the following questions:
-To what extend the formants are suitable to examine and describe the development of human sound utterances?
-Is it possible to print out alterations of the vocal tract caused by the anatomical development and by the neuromuscular activity on the basis of changed formant frequencies?
-Is it possible to take formant extraction as a means to make development processes of CNS including sensoric and motoric systems evident, as far as they are reflected in the system of sound-production as well?

The investigation presented here is regarded a pilot study. It was done as a preparation for more comprehensive longitudinal studies in the framework of the interdisciplinary research project, called "Bio-psycho-social unity of human - being structure and dynamics of the human ontogenesis". Distinguished scientists of the Berlin-Humboldt-University were initiating this project at the Interdisciplinary Institute for the Philosophy of Science & Human Ontogenesis.

METHOD AND MATERIALS

Pre-lingual sound utterances of two unobtrusive boys born at term were analysed. Spontaneous

phonations have been recorded with a cassette tape recorder during the first year nearly weekly. There were cries as well as cooing, babbling and articulations. The proper measurement of the formants was realized by using the Linear Predictive Coding (LPC) method, mainly used in language analysis and synthesis. Each sound utterance was first subjected to a frequency-analysis by means of Fast Fourier Transform after digitating at 21.944 kHz and after adequate preprocessing. As a basis of the calculation were taken 18 sets with 1024 data each per sound - sequence under a spectral resolution of 24.43 Hz. Subsequently the determination of the formants was accomplished by using the LPC algorithm described by Markel & Gray (1976). Twenty coefficient were applied. The formant frequencies and band-widthes evaluated for all sets of each sound signal were interpreted with the inclusion of the proper FFT-spectrum.

A use of LPC for infant sounds is first of all practicable because the basic acoustic assumptions applying to infants and adults are identical. The further interpretation of the results needs to be carried out with the inclusion of the anatomical and physiological special features of infants. As far as I know, cries of newborns only and no other pre-lingual sound utterances were analysed by LPC up to now. For example by Golub (1980) and Bisping (1986).

RESULTS

As is apparent from Table 1, the average values of the first three formants obtained by data of both children largely correspond with the theoretical expectancy ranges estimated according to data of Golub (1980). He took into account the specific conditions in infants and used data of newborns' vocal tract dimensions,obtained by X-ray examination.

formant	average value from the analysis	value estimated theoretically
F1	1200 Hz	1200 Hz
F2	2530 Hz	2700 Hz
F3	3260 Hz	3100 Hz

Table 1. Comparison of the formant frequencies.

The following explanations are related to both children likewise, because essential and similar results were obtained. Formant values of one child are shown in the diagrams attached on the last page.

Apart from two exceptions, the first formant (F1) was found in all sound utterances. While in the period up to about the 20th week the 3rd formant could be identified in almost all analyzed sounds, F2 showed only an irregular occurence during this time. The period after the 20th week presented a different picture: the 3rd formant was noticeably rare to be found while F2 was almost always present.

The first two formants showed a large variation in their frequency ranges. This was the reason to divide the frequency range of F1 into three subrange

1. < 1000 Hz
2. 1000 - 1400 Hz and
3. > 1400 Hz

and the frequency range of F2 into two subranges

1. < 2600 Hz and
2. > 2600 Hz.

The probability of identifying F1 values of less than 1000 Hz is increasing with age. Thus, the values of the first subrange were dominant in the last third of the 1st year. When the development of the 2nd formant is examined it will be clear that there is a tendency towards greater frequency values. Starting from about the 8th month there is a predominance of F2 values greater than 2600 Hz. The frequency range of the 3rd formant assumes relatively constant values. Establishing the ratios between F2 and F1 or, as F2 could not be determined in every case, between F3 and F1 was designed to throw additional light on the changes occurring. The ratio between F2 and F1 is more informative. Its increasing tendency with age is a clear reflection of smaller F1 values and greater F2 frequencies.

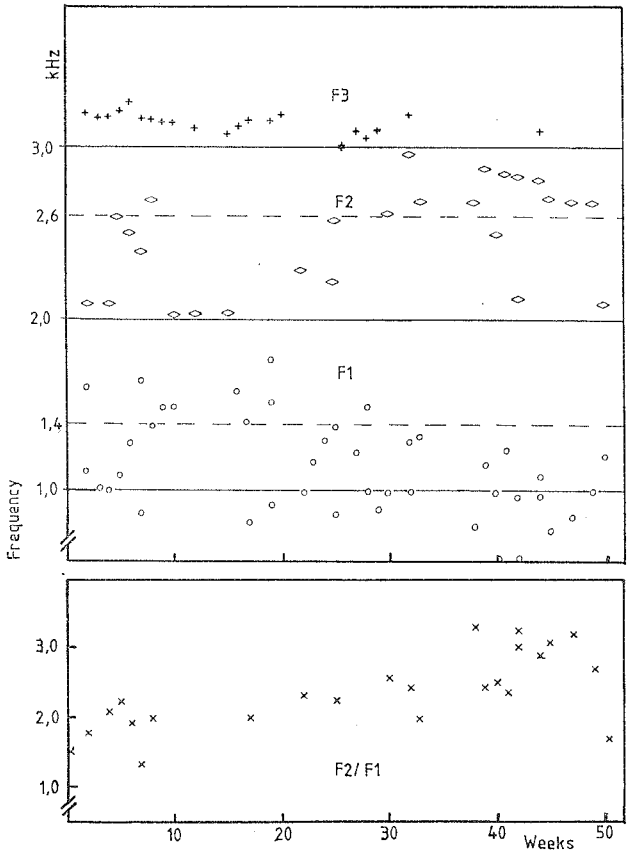
In addition to illustrating the development trends of individual formants, formant variations within sound sequences were of particular interest. Thus, in the sound utterances made during the entire 1st year two or more sections could be distinguished that included clearly different formant frequencies. Results showed that it is mainly the 1st formant which can "travel" continuously from one frequency range to the other, or change discontinuously. The difference between the resultant frequency values was up to 800 Hz. Some examples listed in Table 2 are shown to illustrate these facts.

week	sets	average value of F1
2	1 - 6	1147 Hz
	10 - 13	1648 Hz
7	6 - 8	1679 Hz
	16 - 18	842 Hz
25	1 - 13	888 Hz
	14 - 18	1385 Hz
44	2 - 6	1366 Hz
	15 - 18	988 Hz

Table 2. Examples of formant variations within the sound signals.

CONCLUSIONS

It is seems to be justified to apply the LPC method in combination with the FFT-spectrum to examinate of pre-lingual sound utterances. Examinations showed that the 1st formant has a tendency to reduce its frequency from values more than 1200 Hz in the cries during the first weeks down to an average of 860 Hz in the sound utterances between the 9th and 12th month. While the former values agree with theoretical expectancy range based on the newborn's vocal tract, the latter value corresponds with 1st formant data of some vowels in the language of adults. An example is 750 Hz (Sedlackova, 1967) or 800-1200 Hz (Rieaelnder & Bochinsky,1982) for the vowel [ɑ:]. It is also remarkable that this low F1 frequencies were found irrespective of the type of sound utterance (cry, syllables etc.). Further and detailed investigations of this fact are in preparation. Lindner (1981) found that a reduction in cross-section of the acoustic tube front part leads to lower F1 frequencies. From this one could follow that the increasingly frequent occurrence of lower F1 frequencies is a result of a more or less conscious narrowing of the jaw area. Beyond that this conclusion would emphasize a hypothesis by Bisping (1986) who means that the vocal tract of the newborn already in the first weeks of life showes, that "there exists the principal possibility of generating articulatory processes." There is reason to assume that in the sound utterances without distinguishable 2nd and 3rd formant (mainly after the 20th week) both formants are fused together as a result of changes in the configuration of the vocal tract. Subsequently, articulatory and therefore neurophysiological processes are predominantly represented in the 1st formant while higher formants reflect anatomical and morphological changes during this particular period of ontogenesis.



March of Formants F1, F2, F3 and of Ratio F2/F1

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