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Changes in Prespeech Vocalisations During the First 8 Weeks of Life. A Case Report

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Abstract: Spontaneous cries of a male infant were recorded daily from birth until the age of 8 weeks. Additionally the parents kept a diary reporting the behaviour and the development of the child. Characteristic sounds for each day were investigated using spectrograms and fundamental (melody) analysis. Also changes in the type of melody, mean values of the fundamental frequency, Jitter, perturbation quotients and the occurrence of noisy components were analysed. The data obtained enabled us to locate behavioural as well as prespeech developmental processes in time. Developmental steps, e.g. transition and regression-phases were described for the first 8 weeks of life. Comparing the behavioural reports to the results of the sound analysis a synchronisation was found concerning the manifestation of developmental steps.

Zusammenfassung: *Veränderung der Stimmlaute in den ersten 8 Lebenswochen. Eine Fallbeschreibung.* Bei einem männlichen Säugling wurden von der Geburt bis zum Alter von 8 Wochen täglich Lautaufnahmen spontaner Schreie gemacht. Ergänzend haben die Eltern Tagebuch über sein Verhalten und seine Entwicklung geführt. Charakteristische Laute jedes Tages wurden ausgewählt und analysiert. Neben Analysen im Zeitbereich wurden Spektrogramme und Grundfrequenzanalysen (Melodieverläufe) durchgeführt. Ausgewertet wurden der Melodie-Typ jedes Lautes, die mittlere Grundfrequenz, Jitter, ein Perturbation Quotient und der Anteil von Geräuschkomponenten im Laut. Auf diese Weise wurde untersucht, wann neue Entwicklungsphasen in der vorsprachlichen Entwicklung im Untersuchungszeitraum auftraten. Es wurden ebenfalls „Regressions-Phasen" während der Entwicklung beschrieben. Ein Vergleich mit den Verhaltensprotokollen zeigte, daß sich typische Entwicklungsphasen zeitgleich im Verhalten des Kindes und in Veränderungen seiner Stimmlaute manifestierten.

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Introduction

The cognitive as well as the behavioural development of children reveals several discontinuities. The process of maturation is characterised by the development of single elements which are subsequently differentiated and stabilised. A combination of different separately developed elements can possibly result in a completely new quality (transition). Piaget (1956) described those processes for the cognitive development. The same processes take place in the behavioural development. This is well investigated by van de Rijt-Plooij and Plooij (1992, 1994).

Our former ontogenetic diachronic studies revealed those discontinuities in the prespeech development as well (Schindler 1989; Mende et al. 1990; Wermke and Mende 1992, 1994). These investigations showed, that prespeech development is a good example of the general principles of evolution of complexity (Mende et al. 1990). An healthy infant utters in his first cries only simple elements of intonation, mainly rising-falling melody types. A further differentiation of the cries is characterised by a combination of simple, separately developed patterns. A transition from one level to the next, higher, and more complex level, for example a transition from a simple rising-falling melody pattern to a double arc rising-falling melody pattern, is often connected with so called regression phenomena. During "regression-periods" the cries again sound very immature and their frequency spectrograms resemble those of simple cries of new-borns. In general regression-periods are characterised by the loss of former capabilities, to recapture them suddenly – sometimes on an elevated level.

This case-study investigates when transition and regression phenomena occur during prespeech development within the first eight weeks of life with a high time resolution. We also analysed whether they coincide in time with transition or regression phenomena in gross motor or cognitive development.

Sound production is a highly co-ordinated neuro-muscular process reflecting maturation states of fine motor control mechanisms. Already the production of the apparently simple sounds of crying requires a complex neuro-muscular co-ordination. Whereas the upper parts of the vocal tract are still anatomically and thus functionally immature, laryngeal structures are mature and already capable of well co-ordinated actions. Postnatal maturation and a further training of co-ordinating neuro-muscular actions during the crying-act can be considered as the first step of speech acquisition. This process requires many little sub-steps and is based on general principles of evolution of complexity.

A consensus among researchers has been to view cries beyond the first month of life as more differentiated, more mature and more volitional produced. Compared to the number of authors analysing cry characteristics in certain diseases surprisingly few researchers have evaluated basic developmental characteristics of normal infant crying (e.g. Fairbanks 1942; Sedlackova 1967; Sheppard and Lane 1968; Prescott 1975; Laufer and Horii 1977; Zeskind 1985; Gilbert and Robb 1995).The few existing cry examinations are samples at weekly intervals or even less frequent. The high time resolution of our analysis enables to trace prespeech development more precisely and reduces the probability of overlooking important developmental stages.

The described investigation is a further step to discover and to understand general principles which act during the prespeech development. It supports the hypothesis that speech acquisition starts immediately after birth as well.

Materials and Method

Subject

The subject was a full-term born, healthy boy. Pregnancy and delivery had been without any complications. No indications of abnormality at birth were noted. A neurological examination after birth based on the APGAR-test yielded 8 points after 1 minute, 9 points after 5 and 10 points after 10 minutes. In the course of the first 8 weeks the infant had 3 paediatric examinations. The results reflected a postnatal development within the normal range.

The infant was breast fed on demand.

Data Collection

Daily recordings, with a few missing days (16–22d, 30d, 38d, 45d, 47d, 50d and 52d), of spontaneous vocalisations (cries) have been made from the 9th to the 57th day of life.

All sound recordings were made in a domestic environment. All recorded vocalisations were spontaneously uttered while the infant was lying on a baby-dressing-table. The distance of the microphone to the mouth was 10–15 cm (Sony Electric Condenser Microphone S220). The recordings were made using a DAT-recorder Sony TCD-D3 and DAT Sony DT-60P Cassettes.

Additionally to the recordings, the parents kept a behavioural diary of the child. Beside sleep-/wakefulness times and feeding times of the child, the parents noted behavioural patterns as amount of crying, non-cry vocalisations, demand on body contact, playing etc. The diary documents changes in the behaviour of the child.

Analysis of the Sound Samples

The analysis of the recorded exspiratory cries was made using the KAY Computer Speech Lab (KAY Elemetric CSL-4300). The sampling rate was 50 kHz, the amplitude resolution 16 Bit. The frequency characteristics of sounds can be visualised in spectrograms. The time in seconds is represented on the x-axis, the y-axis stands for the frequency in cycles per second (Hz). The spectrograms obtained by spectral analysis allow for a visualisation of certain acoustic sound features, like fundamental frequency variation in time, the harmonics and the occurrence of noisy components (a great number of sub-harmonics).

The fundamental frequency variations in time were analysed using the Multi-Dimentional Voice Program (MDVP) of the KAY CSL. Results are presented in form of melody graphics (fundamental frequency contours) and amplitude contours. Also statistical values and stability parameters were calculated. As stability parameters we used absolute Jitter, Jitter Percent and a Pitch Period Perturbations Quotient. Absolute Jitter is an evaluation of the period-to-period variability. Jitter Percent describes the relative evaluation of this period-to-period variability. Pitch Period Perturbations Quotient measures the short term irregularities of the

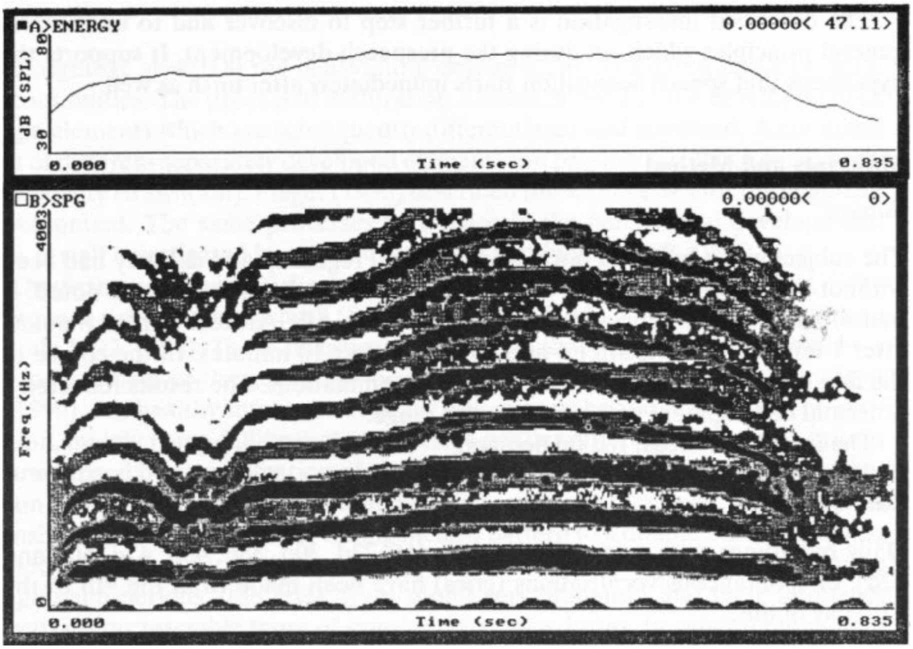

Fig. 1. Energy contour and spectrogram of a typical cry on the 9th day. It shows a slow frequency modulation (melody), describing one short and a second longer rising-falling arc.

pitch period of the voice (smoothing factor of 5 periods). Fundamental frequency variations in time were classified in two types: slow variations (melody) and faster variations (vibrato-like phenomena). The occurrence of the types of variation as such, as well as their combination, have been traced in the course of ontogenesis.

Preceding the spectral analyses, we selected characteristic cries for each day through auditive analysis. In total, the investigation is based on the spectral analysis of 224 cries.

Results

It is well-known from several studies, that in healthy infants prevail rising-falling melody types in the cries during the first days and weeks of life (e.g. Wasz-Höckert et al. 1968; Aulanko et al. 1982; Murry et al. 1983). Analysing the daily recordings we observed beside simple rising-falling melody contours, a more complex melody pattern as soon as on the 9th day of life. A typical melody pattern consists of a short rising-falling arc and a longer, second rising-falling arc at this time (Fig. 1). The analysis of the fundamental frequency (Fo) contour supported the double arc sound structure. At the same time we found fine ripples of the Fo which might still reflect a certain degree of instability. The calculated stability parameters, for example absolute Jitter (Jita), Jitter % (Jitt), or Pitch perturbation quotient (PPQ), reflected the observed instability. The values of these parameters of the cry in Fig. 1 are: Jita = 78.6 μs, Jitt = 3.2% and PPQ = 1.9%.

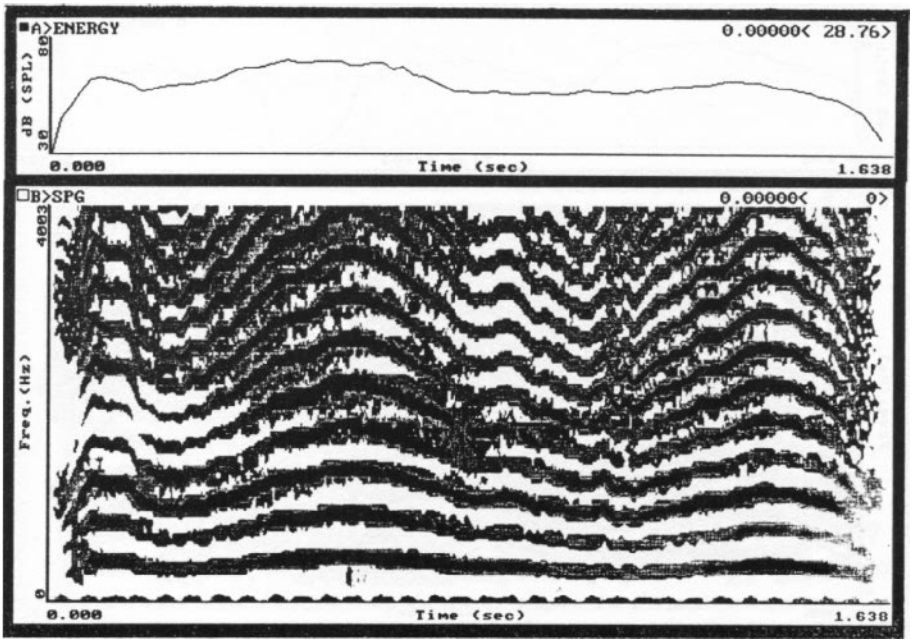

Fig. 2. Energy contour and spectrogram of a typical cry on the 14th day, showing slow fundamental frequency modulations, describing 3 rising/falling arcs. As on the 9th day the cry starts with a short rising-falling part whereas the longer second rising/falling arc now is doubled.

We observed a further development in the cries on the 14th day. Typical for this day is, that many cries show slow frequency modulations in their spectrograms consisting of three consecutive rising-falling arcs. Whereas like on the 9th day the cry begins with a short rising-falling part, the former second longer rising-falling arc is now doubled (Fig. 2). Cries are also longer now, and the control mechanisms underlying sound production are more mature. Although the cries are partially doubled in duration the inner stability of the fundamental frequency contour is much higher. Compared to the former days (e.g. Fig. 1) the values for the stability parameters are as follows: Jita = 23.6 μs, Jitt = 0.8%, PPQ = 0.4%.

After this developmental step, a period of intensive training was observed.

During the next seven days the child uttered cries with flat or simple rising falling melodies, sometimes containing also noisy parts. On some days, the noise was low and modulation of the fundamental frequency rather marked, on others days vice-versa. Some components had been varied and combined, such that frequency modulation occurred at the beginning of a cry as well as at its end, or rising-falling melody-modulations were combined with faster frequency modulations with low modulation depth. Whereas on some days in this span a large variety of vocalisation patterns were produced, on others we only found two or three different ones.

On the 22nd day we observed a new element of the cry repertoire. Some cries showed a clear segmentation: two consecutive rising-falling arcs were separated

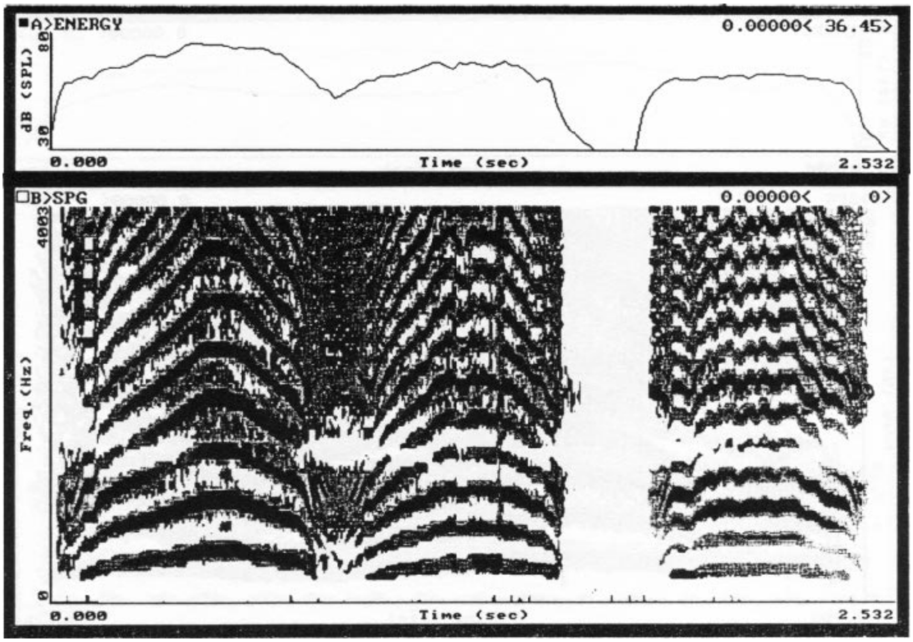

Fig. 3. Energy contour and spectrogram of a cry on the 22nd day. The 3-arc pattern (rising-falling) is well visible. The last arc depicts a lower energy-level than the two earlier ones. Slow frequency modulations exist next to faster ones with low modulation depth. The first arc shows a marked slow modulation, the later arcs more obvious fast modulations.

from a third one by a sharp drop of frequency and amplitude. No inspiration occurred in between these two segments. Whereas the first arc had the most pronounced slow frequency modulation, the second and the third rising-falling arcs had additionally marked fast frequency modulations (Fig. 3). The values of the stability parameters were in between the values of the sounds displayed in Figs. 1 and 2 (Jita = 42.1 μs, Jitt = 1.5%, PPQ = 0.7%). Although the sound is now more complex, the inner stability of the sound producing system is high. Beside this cry-type, the already described simpler cries were uttered.

The described development from simple melody patterns to more complex patterns during the first 3 weeks of life (transition-phase) is suddenly disrupted by a so-called regression-phase between the 23rd and 28th day of life. During this time only simple melody patterns were found in the recorded cries. These patterns were very similar to the cries without complex frequency modulations of the first days. The spectrograms showed also more noisy regions. Slow as well as fast frequency modulations were seldom at this time. This regression phase (23rd–28th day) was relieved from a transition to a new sound quality.

From the beginning of the 29th day (5th week), we found a greater variety of patterns in the cries. The development from the 29th day finished with a further transition to a new sound quality on the 32nd day. Vibrato-like fast frequency modulations with high modulation depth were prevailing. This type of fast frequency modulation was now intensively trained. During this training period the

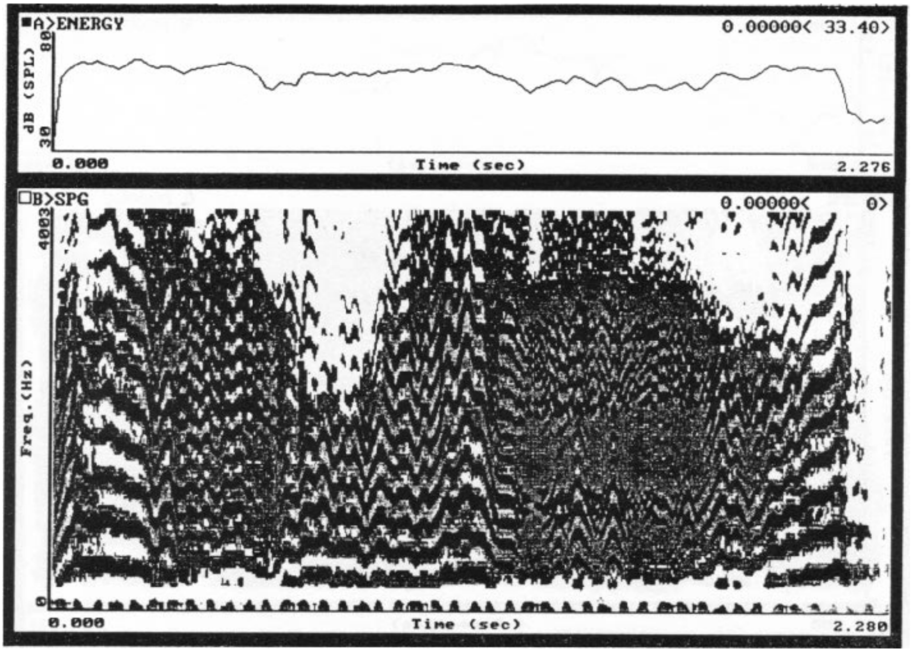

Fig. 4. Energy contour and spectrogram of a cry on the 32nd day. Using a flat melody, vibrato-like fast fundamental frequency modulations are trained. The former well performed slow frequency modulations were transitory "forgotten", a flat melody type was common.

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The time from the 33rd to the 35th day can be viewed as a new regression phase. This time is characterised by an increased duration of the cries and a reduction of slow and fast frequency modulation. Additionally, the part of noisy components is high.

Beginning with the 36th day the frequency modulation increased again. We found vocalisations with a 2-arc frequency modulation, steadily better performed up to the 39th day. At the same time, the part of noisy regions in the cries is much lower compared to the preceding regression phase. Noisy regions mostly occurred at the end of the cry.

For the first time we detected cries with a combination of slow and fast frequency modulations with high modulation depth. This transition to a new sound quality occurred on the 42nd day (Fig. 5). Also for the first time, we observed the attempt of a 4-arcs melody pattern. At the same day cries with 3-arc and 2-arc patterns combined with fast frequency modulation were also observed.

The described development reflects an increase in the complexity of the cries during the 5th to 7th week of life. As a very good example for the reached high complexity is represented in a spectrogram of the 46th day (Fig. 6). A perfect combination of slow frequency modulation (a 3-arc melody pattern) with a very fast vibrato-like frequency modulation was found. The attempt of the new vocal-

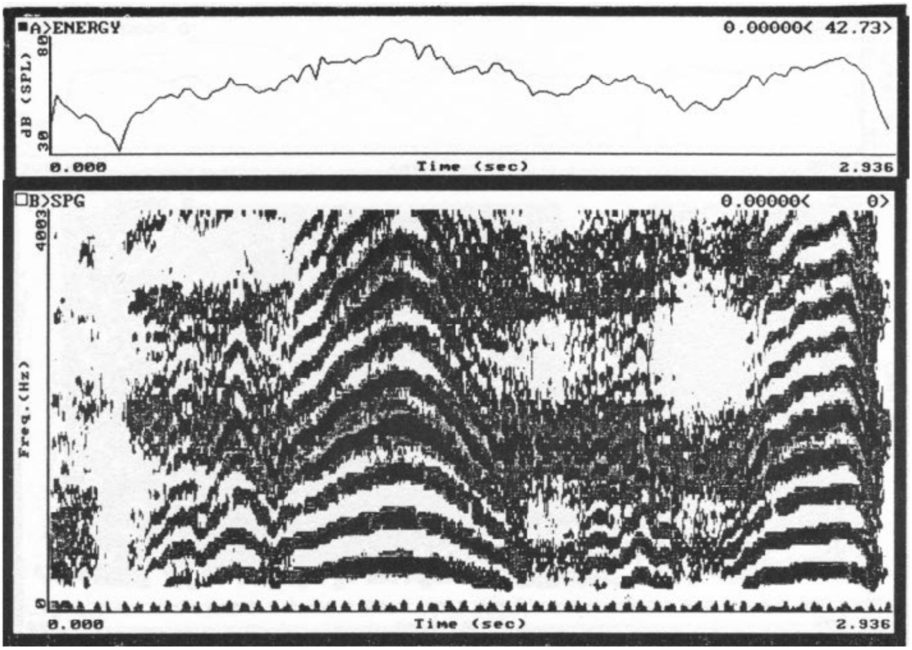

Fig. 5. Energy contour and spectrogram of a cry on the 42nd day. Both show an attempt of 4 rising-falling melody arcs. The instability might be due to the fact, that for the first time complex patterns of slow frequency modulations are combined with fast frequency modulation with high modulation depth.

isation pattern shown in Fig. 5 (42nd day) was now successful. The length of the cries increased too.

A new developmental phase could be observed after the 48th/49th day. As postulated, those maturation steps are always connected with reorganisation processes in the brain. External sign of this reorganisation in the vocalisations is the observed phenomenon, that frequency modulations are worse performed than before. So these days could be considered as a new, slight regression (Fig. 7).

This short regression phase was followed by a second one with simple vocalisations on the 55th–56th day. As well as between this two regression phases, as also on the 57th day, complex sound patterns with marked slow and fast frequency modulations could be found again.

The observed changes in the vocalisations were not in all cases accompanied by behavioural changes.

A good example for the similar developmental phenomena in vocalisation and also in general behaviour of the child, is to be observed in the time about the 4th week. According to the behavioural dairy the parents observed more extensive crying periods during the 4th week, compared to the time before. Additionally the child searched for intensive body contact with the mother at the beginning of the 4th week. Extensive crying is a typical sign characterising a regression phase (for example van de Rijt-Plooij and Plooij 1992, 1994).

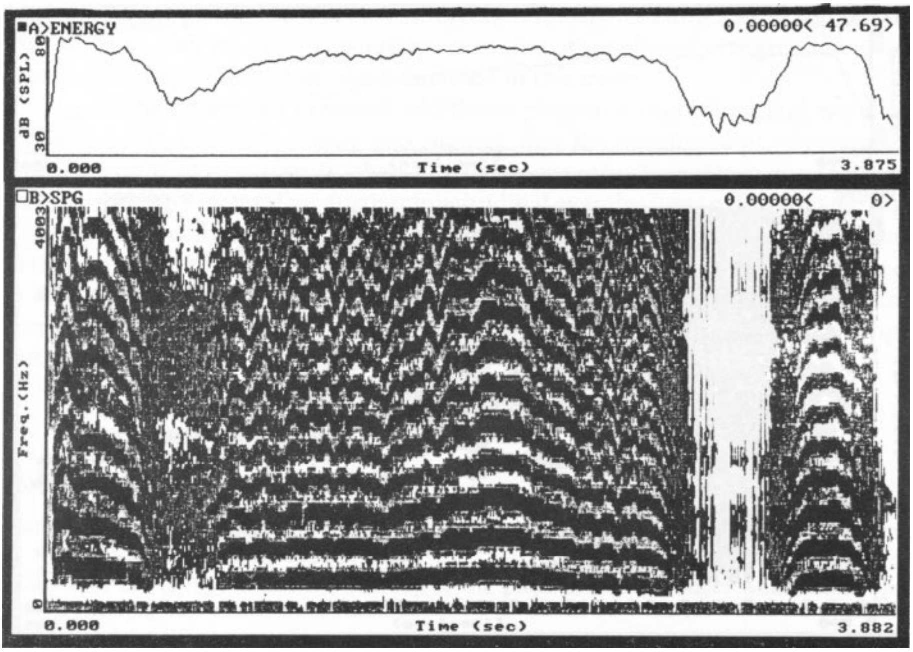

Fig. 6. Energy contour and spectrogram of a cry on the 46th day. A perfect combination of slow frequency modulations and vibrato-like modulations is clearly visible. This new sound quality is connected with increased maturity of the vocal system and the better control of vocalisation.

The suggestion of having a regression phase is supported by our finding concerning the characteristics of sounds uttered during this time.

We observed typical "regressive elements" in the cries, e.g. more noisy regions occurred, frequency modulations were rather seldom during the 4th week.

However the more intensive crying from the 42nd to 44th day was not accompanied by regressions in the uttered sounds.

The following observation is another example for the phenomena, that developmental changes are reflected in the phonation. The parents described in the diary the child changed in a way that it seemed to be more mature when it woke up after a sleep in the late evening at the 35th day. This maturation process perceived by the parents intuitively was again accompanied by an increased frequency modulation in the registered sounds. Similar observations have been made by other parents, whose infants also showed drastic overnight changes.

The recordings of the behavioural changes do not exactly coincide in time with the observed changes in vocalisation. We recorded several 3–6 day periods of intensified crying. These days of crying marked the beginning or the end of transition of vocalisation. The longest period of regression was followed by the longest period of intensified crying (4th to 5th week).

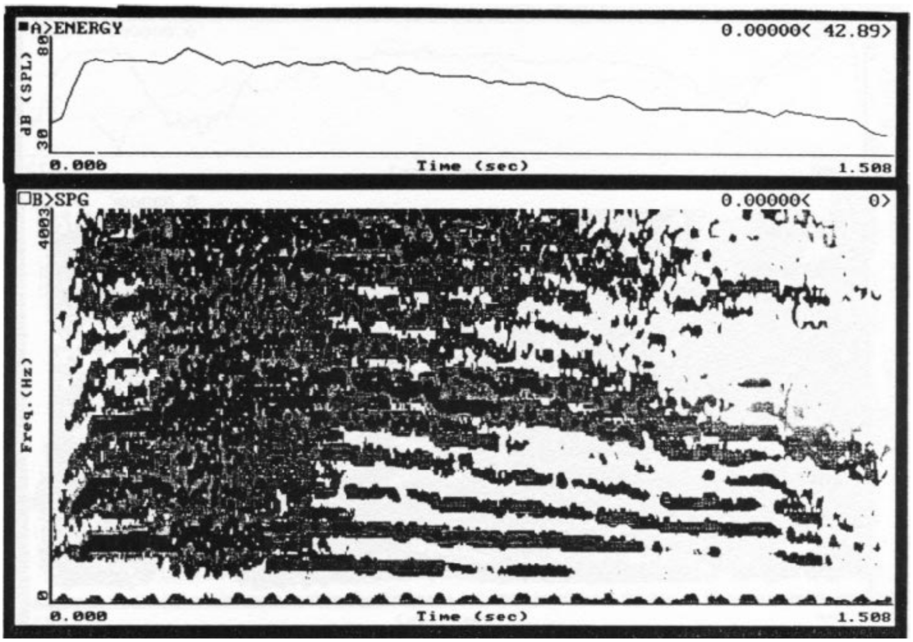

Fig. 7. Energy contour and spectrogram of a cry on the 48th day. The melody pattern is very simple (one rising-falling arc), the fast modulation is also very weak. There is a high part of noisy components, while there are nearly no harmonics visible (It is only 2 days after Fig. 6).

Conclusion

The high time resolution of the described longitudinal examination allowed us to analyse daily characteristics of prespeech vocalisations and infant behaviour in general during the first 8 weeks of life. The results support the hypothesis that prespeech development is a very good example for the general principles of evolution of complexity. It could be shown, that already during the first 8 weeks of life a serie of changes in sound production occurs. Simple elements are separately trained and later combined. Those transitions are disrupted by regression phenomena. Like in former studies we could confirm, that a first regression phase occurs around the 4th week in behaviour as well as in vocalisation. Additionally, we found phenomena which suggest that the second known regression phase about the 8th week (van de Rijt-Plooij and Plooij 1992, 1994) might consist of two different, shorter regression periods. The first regression phase we found was about the 48/49th day, the second one about the 55/56th day. This result is conceivably due to the high time resolution of this study.

We found that large and rapid qualitative changes (transition) occurred quite irregularly and they might be followed by phases of regression of 2–6 days each.

Anyhow, it became quite apparent that the main phases of observed transition and regression followed more or less the time pattern outlined in the existing literature. Van de Rijt-Plooij and Plooij (1992, 1994) pointed to so-called "difficult phases" around the 5th and 8th week of life. During these difficult periods the infants are described as restless, crying a lot, demanding and searching for proximity to their parents. The authors detected other phases of regression which however lay beyond the time span analysed in this study.

For the first time, we detected additional phases of regression and could localise them in time. This study also suggest, that the development of prespeech vocalisation is more dramatic than previously thought. In order to render these results more representative, further longitudinal examinations with the same high time resolution are necessary. Unfortunately, it is sometimes difficult to find parents who are prepared to make recordings over a longer period of time and keep a diary of behavioural changes of their child. Although this study is based on a very small sample indeed, one can conclude that crying is much more than simple utterance of sounds.

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