# Self-generated Sounds in Human Neonates

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## Abstract:

Self-generated sounds, such as cries, are some of the first sensory inputs that the developing brain receives. Eventually, infants need to learn to associate their cries with a caregiving response in order to consciously use crying as a signal. Thus, the acoustic characteristics of their cries are key to neural and behavioural development. This project examines the acoustic features of cries in neonates and discusses how the brain might encode these cries. To explore this topic, existing EEG datasets containing neonatal cry recordings were analysed using MATLAB/EEGLAB, with a focus on the fundamental frequencies of each cry. Results for cry samples are discussed in context with the corrected gestational age of the infant and regularity of cries, and point to how acoustic characteristics may change throughout neonatal crying episodes.

## Background:

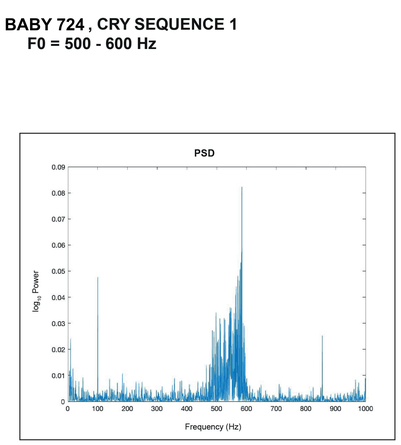
- Vocalisation in humans begins with crying: the key method which neonates use to communicate their needs to the caregiving environment.
- Acoustic analysis of crying can non-invasively assess neonatal health and is linked to neurological damage, prematurity, sudden infant death syndrome (SIDS), respiratory conditions, and hearing impairments. (1,2).
- Vocal fold vibration generates the fundamental frequency (F0), a predominantly analysed feature of infant cries and what we hear as the pitch of the cry (3).
- Previous studies found cries of healthy infants have an F0 of around 200-600 Hz, whilst those of infants with certain pathologies are of a higher frequency (>600 Hz) (4).
- Higher F0 is linked to preterm birth, but this value restores to normal levels at term-equivalent age (5).

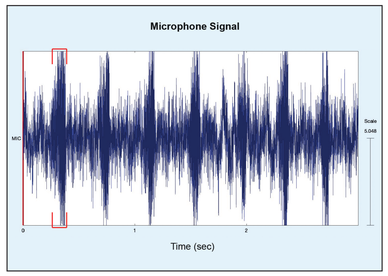
## Methods:

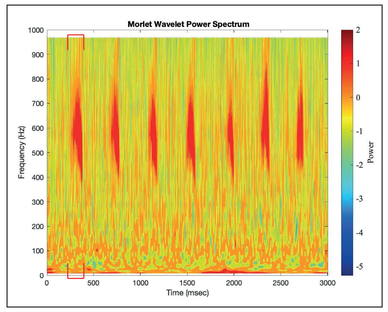
- Recruitment criteria for the cohort of neonates studied:
  - Corrected gestational age (GA at birth + postnatal age) (CGA) between 34 + 5 and 41 + 0 weeks
  - Postnatal age (PNA) of up to 10 days
- Datasets consisted of sound recordings, recorded using snore sensors by SleepSense, with time-locked EEG data. Microphone placed on collar of babygrow to pick up self-generated sounds.
- Sampling rate of recorded signal was 2000 Hz.
- 17 3-second cry samples analysed from 8 different neonates.
- Datasets were analysed in MATLAB/EEGLAB.
- Preprocessing included applying a 6Hz high-pass filter and extracting 3 seconds of crying.
- For each cry/cry sequence, a morlet-wavelet power spectrum was generated along with a power spectral density estimate using Welch's method. From these figures, the fundamental frequency was estimated.

## Results:

**BABY 724 , CRY SEQUENCE 1**
**F0 = 500 - 600 Hz**

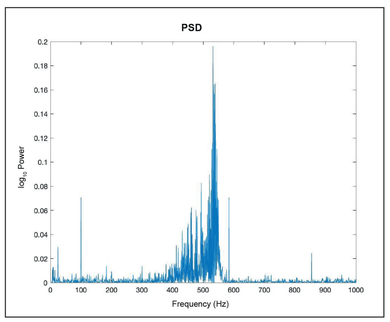


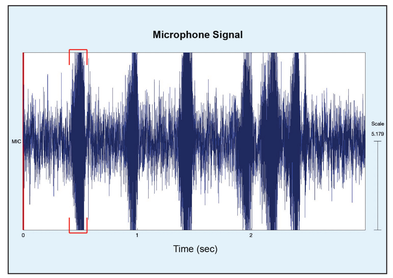




*Baby 724 = Male, Singleton*
*GA=29.86, PNA=40, post-menstrual age (PMA)=35.57*

**BABY 724 , CRY SEQUENCE 3**
**F0 = 420 - 550 Hz**



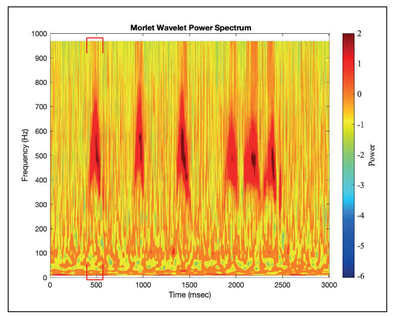




**Fig2.** PSD (left), signal from microphone channel in EEGLAB (top right), and Morlet Wavelet Power Spectrum (lower right) of the third isolated cry sequence in Baby A. The red brackets show where the first of the 6 cries in the sequence is found on both the microphone channel and power spectrum. The estimated F0 for cry sequence 3 in Baby A is between 420 and 550 Hz. There are PSD peaks at lower frequencies and higher powers than observed in Baby A's previous cry sequences.

The results of 2 analysed cry sequences are shown here. Both came from the same baby and occur around 30 seconds from each other.

**Fig1.** PSD (left), signal from microphone channel in EEGLAB (top right), and Morlet Wavelet Power Spectrum (lower right) of the first isolated cry sequence in Baby A. The red brackets show where the first of the 7 cries in the sequence is found on both the microphone channel and power spectrum. The estimated F0 for cry sequence 1 in Baby A is between 500 and 600 Hz. This was estimated by examining the peaks on the PSD and supported by location of the darkest areas (red) in the power spectrum. The deeper colours appear at the time each cry occurs, confirming that it is the cry signal which produces the PSD peaks.

## Discussion:

- Results of cry analysis reflect findings of previous studies, with F0s ranging from 370-600 Hz in all analysed cries
- Some cry samples in Baby A had a lower F0 than others (for instance, min F0 decreased from 500 Hz in cry sequence 1 to 420 Hz in cry sequence 3).
- Figures 1 and 2 show sequences of cries that follow eachother. In addition to the gradual decrease in frequency between sequences, there is also an increase in power observed on each PSD
- Although there were no other cry sequences to see a trend, this may suggest a mechanism is used by the infant to adapt the acoustic characteristics of their cry to elicit a more successful caregiving response (lowering the frequency and increasing the power).

## Future Directions:

- There could potentially be a corollary discharge mechanism used for auditory self-monitoring during infant vocalisation. Marmosets and other nonhuman primates, for example, have shown vocal control in response to auditory feedback of self-generated vocalisations, including adapting the frequency content of vocalisations and increasing vocal amplitude (6, 7, 8).
- In addition, higher F0 and lower intensity cries have been observed in infants with hearing impairments (9). This may be a result of inhibited auditory self-monitoring.
- Future studies should investigate: whether neonates use self-monitoring in an attempt to elicit a more successful caregiving response; the reasoning behind higher frequency cries in infants with certain pathologies (e.g. smaller body size or insufficient neural development); whether preterm infants or those with neurological damage have not developed an effective system for auditory self-monitoring, and thus have higher F0 and lower power cries.
- The analysis of consecutive cry sequences along with EEG data in infants using a larger sample of infants might serve to answer these questions in the future.

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