Pitch Analysis of Infant Crying
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Abstract
Without language competence, cry is a special way that infant express individual needs and response to outside. In this paper, we chose two infants as examinee, measuring fundamental frequency of crying sound section. We developed speech signal analysis platform, and through the analysis we found that infant have falling tone, flat tone, rising tone, rising-falling tone before three month, and there is no corresponding relationship between gender and fundamental frequency of infant crying signal.

Keywords: Infant, Sound Expression, Fundamental Frequency, Platform

1. Introduction
Language is the most important tool for human communication, human through language to convey information. However, language is not in the blood, but acquired through learning and education gradually[1]. Before 1 year old, infant do not have language competence and skills, cry is an important way to express their requirements and wishes, which filled with wealth of emotion, and different cries to express different needs and reactions. From a physiological point of view, crying can increase the negative pressure of the infant's chest, increase lung activity, expansion alveolar, and exercise the respiratory muscles effectively, which is prepare for language production; From the process of psychological development, cry is the first model of children language development, physiological crying could promote infant’s nervous system development and form conditioned response gradually[2], which is an enlightenment of language development in the future; From the point of view of language development, crying is a prelude to speak, which can effectively adjust the high, low, long, short of sound, it is the practice of pronunciation function[3].

The research on infant crying can be traced back to the twentieth century, the study from different angles, including anatomy, psychology, physiology, phonetics and pediatric [4]. The earliest research is based on a hearing to identify a variety of baby crying, research development is with the progress of the acquisition of sound equipment, the first equipment used to study infant crying is Gela Fu to wind the phonograph, with the appearance of tape recorder in 1920 and sonograph in 1940[5], the research has entered a new era. Nowadays, with the widespread use of computer-aided signal processing methods and various physiological instruments and voice analysis software, which are greatly promoted the development and progress of infant crying study [6-7]. The system research of infant crying began in 1960, most of them in Helsinki, Finland, these studies were analyzed by a spectrograph to study cry of health infant and suffering from the disease. Wasz-Hockert and collaborators are the first to use the sound spectrum to study the infant crying and divided the crying into anger, pain and hunger of three categories; Michelsson used sound spectrum to study the crying of newborn babies with choking, cleft palate and bacterial meningitis; several other scientists focused on normal infants from birth to one year old, trying to find out crying characters through study premature and term infants; In recent years, more and more scholars are using time-domain analysis, frequency domain analysis, the language spectrum analysis and signal processing method to analysis infant crying [8-10].

There are also a number of people engaged in the study of infant crying at home, due to lack of objective parameters of acoustic analysis, the early research mainly in the pathological aspects, analysis crying reason through comprehensive judgment, such as the level of infant crying, strong or weak, facial expressions, and the degree of dance for joy, thus to carry out crying categories analysis.
and determine a variety of symptoms of the baby. At the end of the twentieth century up to now, along with the development of domestic phonetics, some linguists also gradually using acoustic method to analysis the rich information which contains in the baby crying sound. Li Shihong (1995) using the three-dimensional dynamic mapping method analysis of 20 cases of normal infants less than six months[11], and 40 cases of non-normal baby cry resonance and fundamental frequency, and consider normal baby crying fundamental frequency below abnormal baby; Yuan Fengling (2011) studied characteristic analysis and recognition of baby crying sound through computer signal processing method, using MFCC parameters to analyze the impact of recognition rate of the different growth stages of pain and non-pain cries[12-13].

2. Characteristics of Infant Crying

There are many types of infant crying, such as wail, sobbing, really crying and false cry, etc. In the former study of infant crying category, there are many types of classification, mainly for the following two:

Firstly, Physiological crying and Pathological crying. Physiological crying is baby’s instinctive reaction, such as hunger, thirst, urine, lack of sleep, shocking, crying features are more regular, smooth, homogeneous, and gentle which can stop after comfort. Crying can be divided into tears, big cry, small cry and tentative cry. Big cry have a loud rhythmic, longer expiratory cry unit and whimper while small cry sounds are gentle and intermittent, tentative cry sounds are more lower with different lengths and have no sense of rhythm, which often between sobs and crying, after calming, baby stop crying immediately. Pathological crying is baby suffering from certain diseases, leading to discomfort or pain, without prior whimper, no small cry, but suddenly loud exhale, inhale, then exhale, thus caused a series of sharp and rapid crying sound. In general, infant not have an obvious pathological signs at an earlier stage of the disease, crying is often the mainly an early pathological performance. The crying of and illness are quite different, and crying will stop only when the infant pain was relieved. The crying of sick baby is always usually with small volume while the crying of aching baby is always sharp and shortness [14].

Secondly, Pain crying and Non-pain crying. Pain crying is generally in a quiet state, when human acupuncture or hurt infant, and infant crying due to intense pain. And signal acquisition is difficult and need special circumstance. Non- pain means baby’s spontaneous crying which occurs in a quiet and nature state [15].

2.1. Principle research of infant vocalization

Figure 1. Infant pronunciation organs

Voice is uttered by human vocal organs; the mature of vocal organs is an important physiological premise of children's language occurrence and development. Structure and physiology of young children’s respiratory system have some differences with adults, according to research, the shape of human infant pronunciation organs are similar to primates, such as monkeys, orangutan’s babies who can not issue speech sound. Compared with adults, baby has some special breathing system features: 1)lung elastic fiber development is not good, with small number of alveolar, alveolar volume is less than an adult, and less ventilation volume; 2) throat is narrow than adult, rear position is relatively high, vocal cords and mucous membranes are relatively soft, vocal cord is short and thin, thus the tone of early children are sharp than adults; 3) soft palate is bigger, and the soft palate and epiglottis formed double seal in the mouth, tongue has a large proportion in the mouth; 4) nasal cavity and nasal passages are relatively small and narrow, no nose hair, thus baby can only use the nose breath, when
nasal obstruction, and young children usually do not breathing by mouth. See figure 1, figure 2. (Note: Li: lip; HP: hard palate; T: tongue; M: jaw, SP: soft palate, E: epiglottis, La: throat)

Because children chest is narrower, the respiratory muscle growth is not perfect, so breathing strength is weak, and each inspiration and expiration are shallow, the amount of breathing of each time is also less than adult. Generally speaking, newborn breaths per minute is about 40 to 50 times, two to three-year-old child breathing is 20 to 30 times per minute, adult breathing is 10 to 15 times per minute, thus the younger age the faster frequency, and the poor breathing rhythm. With the growth and development, the baby's throat position are gradually decline, and the throat are dropping to the pharynx position in three months, at the same time, the nasal cavity to the pharynx no longer is a sealed channel, mouth began to participate in breathing. In addition, due to the baby's pharyngeal cavity and the position of the vocal cords is shorter, throat position is higher, the mouth to the pharyngeal cavity is a tilt state, and pharyngeal and epiglottis are closely linked, thus the nasal phenomenon is more serious during baby crying.

2.2. The signal characteristics of infant crying

Because of the limitation of special Physiological sound structure, there is a significantly difference between infant crying sound and adult speech sound. It can be seen from the diagram: 1) fundamental frequency is high. In chart (a), infants’ fundamental frequency range from 400 Hz to 500Hz. In chart (b), adult’s fundamental frequency range between 200 Hz to300Hz, because the baby's vocal cords is shorter and thinner than an adult, thus baby's fundamental frequency is generally higher than an adult; 2) F2 is relatively larger. Because tongue takes a larger proportion in the infant's mouth, and the tongue is in the front position during the pronunciation; 3) Frequency spectrum pattern of crying sound is irregular, crying rhythm is related to the breath cycle; 4) The time difference of each crying sound units are quit larger. During crying, not only different baby have different crying duration, also there are larger different crying duration of the some infant in each crying section, the beginning and the end of each crying sound units are also have different crying duration, thus, we could use time difference of crying sound to distinguish crying type effectively. The time difference of crying unit could reflect the baby's physiological characteristics, such as comfortable degree.

3. Signal acquisition and realization of analysis platform

In this article, on accounts of the young age of subjects, we are using the natural sampling method, the subjects are two young healthy infants, one is a girl, and anther is a boy. We are using the recording pen to record two infants’ crying sound during daily life before 12 week, the sampling rate of recording pen is 44K, and recording format is the wav file of PCM code.

First of all, we are tracking recording to two infants, and three times a week. The recording environment mainly in children's home and avoid noise. Through comfort and guide, we lead infant to make sound, and then record the crying sound during baby in hungry, sleepy, urine.
Secondly, develop the speech signal analysis platform. Through MATLAB, we developed the speech signal analysis platform. The platform can realize sound broadcast, syllable segmentation, and display waveform’s spectrogram, amplitude, energy, frequency curve of each sound file in the same time.

![Image](a)

![Image](b)

![Image](c)

![Image](d)

**Figure 3.** Spectrogram of infant crying signal and adult speech signal

Note: [a] fundamental frequency curve of infant crying; [b] fundamental frequency curve of speech; [c] waveform diagram of infant crying; [d] the sonogram of infant crying signal

Finally is the analysis of parameter. Parameter analysis includes three parts:

1. **Syllable segmentation.** Compared with adult speech signal, infants crying signal are both similar and different with an adult. Except crying sound, each recording also includes noise, pause, burp and cough. We only keep crying sound after segmentation, and each crying sound segment includes: silencing segment, transition segment, speech segment, and the end. Through the phonetic analysis platform, it can syncopate crying sound automatically. Firstly, cut a voice segment into several syllables automatically; then name each syllable automatically according to segmentation order, and saved in the corresponding file folder.

2. **Marking.** Using the speech analysis software Wave final extract fundamental frequency mark and formant mark of each syllable in the folder.

3. **Parameter analysis.** Using speech analysis platform to open the speech file again, this can batch display the corresponding acoustic map of each syllable, and smooth frequency curve automatically, as shown below.

4. **Tone analysis of crying signal**

Pitch period is an important parameter of the speech signal, which can produce fundamental frequency F0 when the vocal cords vibration, the pitch of sound is changed with the change of
fundamental frequency. Fundamental frequency has much to do with length, thickness, toughness of vocal fold, children’s frequency are usually between 200-450Hz. In the early forty or fifty's, foreign scholars used experimental methods to the analysis the vowels acoustic features, and classified children, woman and man's fundamental frequency, they all reached a decision that children have the highest frequency.

Since the human voice signal is a non-stationary time-varying signal, while the change speed of the vocal organs are much slower than the change of the sound, Thus, we can assume that the speech signal is short-term and steady in the range of 5-50ms. We use speech signal analysis platform to Frame and window of the original signal, because the voice fundamental frequency range is in 50-450Hz, we choose the frame length is 10-20ms Hamming window, frame between overlap.
Infant crying pitch range is between 200-1000Hz, and fundamental frequency average is 450Hz, common fundamental frequency range is between 300-600Hz, based on the crying frequency analysis of two babies before three months, we got the following conclusions:

1) Pitch curve patterns have falling tone, flat tone, rising tone, rising-falling tone, rising-falling-rising-falling tone, (Figure 5). Newborn baby’s frequency curve is a simple level tone within a week, with growth, curve pattern presents diversification, appear flat in 15 days, appearing rising-falling tone after a month, and appearing rising-falling-rising-falling tone in two months later.

2) In early three months, infant crying pitch curve model is mainly rise-falling, and each crying sound unit have a falling tendency in the end. During expiratory crying, vocal fold tension and subglottic pressure gradually decreased, crying frequency is also gradually reduced, as shown in Figure 6, Figure 7.

3) In a section of a crying signal, crying sound units are more than the silencing segments. A complete the cry unit should include inspiratory crying segment and expiratory crying segment. Generally inspiratory crying lasted a relatively short period of time, most are unvoiced, sometimes are voiced, the average time is 0.3m, without stability, after inspiratory crying, some of them have a brief pause, some are not, both are followed by an expiratory crying section. Expiratory crying signal time is longer, crying along with vocal fold vibration, and each expiratory crying time duration are quite different, the pause length less than one second.
4) As the baby special vocal structure, their crying signal often following leakage, and vocal cycle regularity is poor.
5) The pitch contour of infant crying is not related with gender. In adult speech signal, the woman’s fundamental frequency is usually higher than man, but there is no corresponding relationship between gender and fundamental frequency in our collection of infants crying signals.

6. Conclusion

In this paper, we analyzed the pitch variation of two infants’ crying signal before three month, although there are personality differences in the change of the pitch, we still have rules and common features. In a previous study, there are less research results concerning the infant crying in domestic, this article is a tentative research, and based on a small amount of corpus, we hope to analysis baby cry based on more subjects and more corpuses in the future.

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8. References

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