Acquisition methodology of the newborn's crying

Metodologia de achiziție a plânsului nou-născutului

**Elvira Brătilă[1],
Diana Comandasu[1],
Ștefan-Stelian Diaconescu[2],
Mircea Sorin Rusu[2],
Gheorghiță Sardescu[3]**

1. Department of Obstetrics and Gynecology, "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania; "St. Pantelimon" Emergency Clinical Hospital, Bucharest, Romania
2. R&D Department S.C. SOFTWIN SRL Bucharest, Romania
3. Department of Neonatology, "St. Pantelimon" Emergency Clinical Hospital, Bucharest, Romania

Correspondence:
Elvira Brătilă
e-mail: elvirabarbulea@gmail.com

Abstract

Crying represents the initiation of human vocal communication, as it is the most important mean of transmitting infant's needs and wants. This article provides the necessary information for designing the collecting system of newborn's crying and associating it with their physical condition. The study involves the development of a database with information about the full needs of newborns and infants expressed throughout crying. It includes newborn babies with a gestational age at birth more than 34 weeks, and chronological age (or corrected age for premature babies) smaller than 3 months. After analyzing the specialty literature we identified 6 types of crying in healthy newborns, associated with different needs, and the pathological crying. The 6 physiological crying types are caused by hunger, pain, postprandial or belching, fatigue or sleep, minor discomfort and abdominal colics. For each type of crying to be identified we will highlight: the stimuli (if applicable) applied to the subject to produce the type of crying, the moments of time in which the likelihood of appearance is highest or any dependencies between the types of crying. Crying will be acquired in the maternity and at domicile of subjects and data acquisition will be performed by specialized personnel (in the nursery) or parents (at home). For each subject will be stored in the database information to characterize the newborn, regarding in particular the parameters of the birth. Depending on the characteristics at birth (gestational age, weight, health status, Apgar score), newborns can be grouped into three categories: healthy term newborn, at risk newborn, sick newborn. Besides acquisition of the needs associated with crying, other information will be retained for each record of crying: the need that labels the cry (of the 7 types listed), the subject's age (0-3 months), the time of the acquisition of crying, the recording location (maternity or home), the date of registration, the time from the last meal, the type of diet (milk or formula, if relevant), the time from the last sleep (depending on the sleeping and waking pattern). The main purpose of the video recording application is to allow the association between infant crying and its condition. We chose filming not only sound in order to facilitate the labeling of offline data by health care professionals and to create the foundations for the development of algorithms recognition that use images as complementary information. The study of recognizing newborn and infant's language by finding correlations between their crying and their physiological or pathological needs is an ongoing project, which will bring a real help to both parents and medical personnel involved in treating and attending babies.
Keywords: *newborn language, crying, acquiring vocal signals, sound reflexes*

Rezumat

Plânsul reprezintă inițierea comunicării vocale umane, fiind cel mai important mijloc de transmitere a nevoilor și dorințelor sugarilor. Acest articol furnizează informațiile necesare pentru proiectarea sistemului de colectare a plânsului nou-născuților și asocierea acestuia cu starea lor fizică. Studiul implică dezvoltarea unei baze de date cu informații despre nevoile complete ale nou-născuților și sugarilor exprimate prin intermediul plânsului. Acesta include nou-născuții cu vârstă gestațională mai mare de 34 de săptămâni la naștere și vârstă cronologică (sau vârstă corectată pentru copiii prematuri) mai mică de 3 luni. În urma analizei literaturii de specialitate am identificat 6 tipuri fiziologice de plâns la nou-născuți sănătoși, asociate cu nevoi diferite și plânsul patologic. Cele 6 tipuri de plâns fiziologice sunt cauzate de foame, durere, post-prandiale sau eructații, oboseală sau somn, disconfort minor și colici abdominale. Pentru fiecare tip de plâns ce va fi identificat, vom evidenția: stimulii (dacă este cazul) aplicați subiectului care generează tipul de plâns, momentele de timp în care probabilitatea de apariție este mai mare sau orice dependențe între tipurile de plâns. Plânsul va fi achiziționat în maternitate și la domiciliul subiecților și achiziția de date va fi efectuată de către personal specializat (în maternitate) sau părinți (la domiciliu). Pentru fiecare subiect vor fi stocate în baza de date informațiile personale, în special în ceea ce privește parametrii nașterii. În funcție de caracteristicile de la naștere (vârsta gestațională, greutate, stare de sănătate, scor Apgar), nou-născuții pot fi grupați în trei categorii: nou-născut la termen sănătos, nou-născut cu risc, nou-născut bolnav. Pe lângă achiziționarea nevoilor legate de plâns, alte informații vor fi păstrate pentru fiecare înregistrare a plânsului: nevoia ce cauzează plânsul (din cele 7 tipuri enumerate), vârsta subiectului (0-3 luni), timpul de achiziție a plânsului, locația de înregistrare (maternitate sau domiciliu), data de înregistrare, timpul scurs de la ultima masă, tipul de dietă (alăptare sau formulă), timpul scurs de la ultimul somn (în funcție de modelul de somn și veghe). Scopul principal al aplicației de înregistrare video este de a permite asocierea dintre plânsul sugarului și starea acestuia. Am ales filmarea în detrimentul înregistrării audio în scopul de a facilita etichetarea datelor offline de către personalul medical și de a crea bazele pentru dezvoltarea de recunoaștere a algoritmilor ce folosesc imagini și informații complementare. Studiul de recunoașterea limbajului nou-născutului și sugarului, prin identificarea de corelații între plâns și nevoile lor fiziologice sau patologice, reprezintă un proiect în curs de desfășurare, care va aduce un real ajutor pentru ambii părinți și personalul medical implicat în tratarea și îngrijirea copiilor.
Cuvinte-cheie: *limbajul nou-născutului, plâns, achiziția semnalelor vocale, reflexe de sunet*

Aim of the study

The aim of this project is to design and build a system of automatic recognition of newborn and infant's cries until the age of 3 months. These cries correspond to the needs or condition of the child. The system should support both the inexperienced parents and trained staff in order to be able to suggest and identify the cause of crying.

In order to achieve this objective, our project includes the development of a crying platform which will allow the validation of the methods proposed for recognition. The study involves the development of a database containing information about the full needs of infants expressed throughout crying. This database will be formed by the acquisitioning and labeling of newborn cries up to 3 months of age.

Introduction

Crying represents the initiation of human vocal communication, being the main method of transmitting the infant's needs and wants. Crying features have been first studied using musical notation, line drawings or wax cylinder recordings. The appearance of the spectroghraph lead Lynip to conclude in 1951 that newborn cry could be differentiated by spectrographic analysis in two major types: a pain cry and a basic cry, which is most frequently identified and often associated with hunger (Wolff, 1969). After that, different studies conducted mainly in Scandinavia (Truby and Lind, 1965, Wasz-Hockert, Lind, Vuorenkoski, Partanene and Valanne, 1968, Karelitz and Fisichelli, 1962, Wolff, 1969) showed that newborns with brain disorders have different cries compared to normal infants. This discovery opened a wide field of research in order to determine if cry analysis is a useful tool in dealing with infants with different medical conditions.

The act of crying is complex, involving the coordination of respiratory, laryngeal and supralaryngeal movements, directly related to the infant's neurological integrity, which is why it offers information about the infant's central nervous system. The subglottal system and the larynx control characteristics of the cry including pitch, timing and intensity, while the supraglottal one is responsible for the formant frequencies, being in close relation to the shape of the upper airways and their motor innervation. The components of the central nervous system involved in the control of infant crying include the brain stem, midbrain and limbic system, and ulteriorly the cortex. Crying appears in the expiratory time of the respiration, the larynx being responsible for the phonation or production of sound when the drop of pressure in the glottis causes the vocal cords to adduct and vibrate. This is called fundamental frequency or what we hear as voice pitch. After that the sound from the larynx is modified through the airways and generates the resonance frequencies or formants. Formants are usually related to language that is why recent studies have showed that maternal language has a major impact on the newborn's crying (Mampe, Friederici, Cristophe, Wermke, 2009).

The act of crying precedes the linguistic phase in infants but at the same time includes prosodic and qualitative features of language like inflection patterns, intonation, melodicity and intensity. In the animal regnum these features represent the modality to call and signal one another, in other words to communicate. An interesting similarity between the newborn's anatomy and the one of nonhuman primates is the high position of the larynx at birth, which descends at about 3 months of age being repositioned in the pharynx, which causes a change in vocal sounds of infants around that age.

Interest in this topic is major because crying is the only form of communication in case of newborn and infant. The infant's cry sends a multitude of physical and mental sensations, most often misunderstood at the beginning by the mother or his entourage. The baby cries differently depending on clinical condition, if healthy or sick. Prolonged crying is a source of stress for parents, especially during the first months of a baby when they are all in the accommodation period. Automatic interpretation of infant's cry therefore, is beneficial for the entire family, and on a greater scale, the entire society.

The Dunstan Baby Language is a system invented in November 2006 by Priscilla Dunstan, a former mezzo-soprano and a mother who claims to have a photographic memory of sound, describing what she calls vocal reflexes as communication signals in infants between 0 and 3 months. It identifies 5 types of sounds that regardless of culture and linguistic groups have different meaning in the language acquisitioning period of infants. According to Dunstan's theory, human reflexes like hiccups, sneezes and burps have a recognizable pattern when they are added sound. Sound reflexes present in babies until the age of 3 months are a distinct type and generate what she calls a preemptive cry characteristic to a specific need (food, comfort, sleep), which turns into hysterical cry if the need is not responded. After 3 months of age while the infant matures in vocalization, the sound reflexes are replaced by babbling. However, the Dunstan method has not been supported by major studies or widely accepted.

Based on Dunstan Baby Language and the analysis of the specialty literature, we identified 6 types of crying in healthy newborns and infants, associated with different physiological needs as well as the pathological crying. The 6 physiological crying types are caused by hunger, pain, postprandial or belching, fatigue or sleep, minor discomfort and abdominal colics. The validation of the results is based on the collection of data in the literature combined with the experience of the neonatologists from "Saint Pantelimon" Hospital.

For each type of crying to be identified, we will highlight: the stimuli (if applicable) applied to the subject in order to produce the type of crying (i.e. the time of vaccination in maternity could be a trigger of crying associated with pain), the moments of time in which the likelihood of appearance is highest (i.e. for the cries associated with the need for food we could make time estimations taking into account the time of the last meal), any dependencies between the types of crying (i.e. it is possible that after the crying of hunger to occur the postprandial cry associated with belching if the baby is not helped to remove the air swallowed with milk).

Crying caused by pain requires no other validation methods. It is recorded while carrying well established routine normally carried out every day and about at the same time. In the maternity there will be 3 registration moments, during hepatitis and tuberculosis immunizations

and capillary puncture for metabolic testing. Hepatitis and tuberculosis vaccination will be done immediately after birth, while metabolic testing will be performed at 48 hours of life.

Crying triggered by hunger is identified by the combination of several elements like: appearance at an interval of 2-3 hours after the last meal, preceded by agitation, lip movement, reflex search, rotating head, touching the lips, sucking the finger, cessation after administration of milk. According to Dunstan's theory, the sound reflex associated with hunger is 'Neh', produced when the sucking reflex is triggered, which pushes the tongue up on the roof of the mouth.

Postprandial or belching crying is validated by the following characteristics: the appearance of crying after food administration, the absence of other health problems, the lack of interest in eating expressed by the child, verified by offering implementing bottle or breast, and if the child is helped to eliminate the air swallowed during feeding, the baby stops crying and settles. The need to be burped is expressed according to Dunstan by the sound 'Eh', produced when a large trapped bubble of air is caught in the chest and the reflex tries to release it out of the mouth.

Crying caused by fatigue or sleep can be distinguished as it is preceded by movements of rubbing the hands over the eyes and if the child is comforted and put to bed by his mother, the crying ceases. Dunstan identifies the sound reflex associated with sleep similar to an audible yawn, in the form of 'Owh'.

Crying caused by minor discomfort can be recognized because it seems an inexplicable crying. The discomfort may be caused by an unchanged diaper, uncomfortable clothes, crib or blankets that bother the baby, being necessary to exclude other causes of crying: hunger, belching, sleep, colic and if the cause is discovered and removed, crying ceases. Dunstan's description of this vocal reflex related to communicating stress is 'Heh', the sound being often produced by a response to a skin reflex, such as feeling sweat or itchiness.

Crying caused by abdominal colic can last for long periods, occurs between meals and is accompanied by frictional movement of the feet or lifting the knees in order to compress the abdomen to expel air accumulated, abdominal distension and gurgling. This type of crying calms if the infant is placed prone on the mother's abdomen or if the belly is rubbed clockwise. The sound produced by the baby in this case according to Dunstan is 'Eairh', produced when trapped air from a belch is not released and reaches the stomach and intestine where the muscles contract in order to get the air bubble out.

Pathological crying is suspected when previous versions were excluded and the infant shows signs of a disease known whether or not by the parents. Dunstan calls it hysterical crying, but all the causes mentioned above need to be checked first, as this the hysterical cry can be caused by each of them if the need that caused it is not satisfied.

Material and method

The study involves the development of a database containing information about the full needs of newborns and infants expressed throughout crying. It includes newborn babies with a gestational age at birth more than 34 weeks, and chronological age (or corrected age for premature babies calculated as the difference between the chronological age and the number of weeks needed for the birth to be at term) smaller than 3 months, born at the "Saint Pantelimon" Clinical Emercency Hospital Maternity. All mothers gave their informed consent for the participation in the study, either in the maternity, at home, or both. Crying will be acquired in the maternity and at the domicile of subjects. Data acquisition will be performed by specialized personnel (in the maternity) or parents (at home).

The advantages of acquisitioning the data in the maternity are that specialized trained personnel is in charge of the acquisition, a small number of acquisitioning terminals can be used to analyze several newborns and labeling the data gathered can be done at the same time by specialized staff. On the other hand, the disadvantage is the limited period in which they can acquire the cries of subjects, which in healthy term newborns is 2-3 days.

The advantages of acquisitioning the data at home are that the acquisition may take place over a period of time and the subject is better accustomed to his environment, which decreases the chances of crying due to several needs (in this case crying associated stress, for example). The disadvantages include the fact that data acquisition is performed by parents and errors may occur during acquisition and labeling data cannot be achieved at the time of acquisition.

For each subject there will be stored in the database information to characterize the newborn, regarding in particular the parameters of the birth. These data are entered only once with the occasion of the addition of the subject to the system: ID of the subject, sex, date of birth, Apgar score, birth weight, gestational age, clinical state (healthy or sick), pathology in case of a sick newborn, the modality of birth (spontaneous or cesarean section), length, child rang, type of pregnancy (unique or multiple) and whether the pregnancy was with risk. Besides acquisitioningthe cries associated with different needs, the following information of the subjects will be noted for each record of crying: the need which labels the cry (of the 7 types listed), the subject's age (0-3 months), the time of the acquisition of crying, recording location (maternity or home), date of registration, the time the last meal of the subject took place, the type of diet (milk or formula, if relevant), the time last sleep took place (depending on how were the sleeping and waking topic), information about the environment, e.g. temperature (and possibly humidity), information about the health of the subject and information on when the diaper was changed (and if pampers were full).

For every crying a simple procedure will be followed by the child's parent or by specialized staff in order to satisfy the need associated with that cry. For example, if the subject complains of hunger, administering milk will determine the subject to stop crying. Parents will be asked to keep a diary of the infant during the period in which they record their cries. It will be in a form as in the following table and will contain the following information for each day of recording.

Discussions

The main purpose of the video recording application (audio and video) for acquisitioning newborn cries is to

Table 1 Labeling data offline form

Subject ID number	123		
Date	15.03.2015		
Meal hours	2:00; 5:30; 9:15;...		
Sleep hours and suration	3:00 (2 hours); 7:00 (1hour and 30 minutes); ...		
Diaper changing hours	2:30; 6:00; 8:45; ...		
Alimentation	■ **Formula**	**Breastfeeding**	
	■		

Recordings	Hour	Clinical observation	File name	Need	Validation
1	10:00		20430	3	
2	11:30		20431	1	
3	17:00		20432	6	
4	20:00		20433	2	
5					
6					

allow the association between infant crying and their condition. We chose filming, not only sound, in order to facilitate the labeling of offline data by health care professionals (e.g. facial expression during crying can provide information about significance), and to create the foundations for the development of recognition algorithms that use images as complementary information.

Depending on the characteristics of the birth (gestational age - GA, weight, health status, Apgar score), newborns can be grouped into 3 categories: healthy term newborn: GA 37-42 weeks with appropriate weight according to GA intrauterine growth and maturing curves after Lubchenco without clinical signs of disease, Apgar greater than or equal to 8, risk newborn: premature, postmatur or dismatur - SGA (small for gestational age), macrosome or LGA (large for gestational age) and sick newborn: with respiratory, neurological, cardiac, gastrointestinal or infectious pathology, genetic syndromes etc. (regardless of weight and GA). This provides the opportunity to observe if there are significant differences between the three categories of infants regarding the crying pattern.

Conclusions

The study of recognizing newborn and infant's language by finding correlations between their crying and their physiological or pathological needs is an ongoing project, which will bring a real help to both parents and medical personnel involved in treating and attending babies. ■

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