Available online at www.sciencedirect.com

ScienceDirect

Speech Communication 58 (2014) 91–100

SPEECH COMMUNICATION

www.elsevier.com/locate/specom

Infant cry reliability: Acoustic homogeneity of spontaneous cries and pain-induced cries

Tanja Etz [a,b,*], Henning Reetz [b,1], Carla Wegener [a,2], Franz Bahlmann [c,3]

[a] Fresenius University of Applied Sciences Idstein, Limburger Straße 2, 65510 Idstein, Germany
[b] Department of Phonetics, Goethe University of Frankfurt, Senckenberganlage 31, 60325 Frankfurt, Germany
[c] Bürgerhospital Frankfurt am Main, Nibelungenallee 37-41, 60318 Frankfurt, Germany

Received 12 April 2013; received in revised form 22 October 2013; accepted 14 November 2013
Available online 28 November 2013

Abstract

Infant cries can indicate certain developmental disorders and therefore may be suited for early diagnosis. An open research question is which type of crying (spontaneous, pain-induced) is best suited for infant cry analysis. For estimating the degree of consistency among single cries in an episode of crying, healthy infants were recorded and allocated to the four groups spontaneous cries, spontaneous non-distressed cries, pain-induced cries and pain-induced cries without the first cry after pain stimulus. 19 acoustic parameters were computed and statistically analyzed on their reliability with Krippendorff's Alpha. Krippendorff's Alpha values between 0.184 and 0.779 were reached over all groups. No significant differences between the cry groups were found. However, the non-distressed cries reached the highest alpha values in 16 out of 19 acoustic parameters by trend. The results show that the single cries within an infant's episode of crying are not very reliable in general. For the cry types, the non-distressed cry is the one with the best reliability making it the favorite for infant cry analysis.

Keywords: Infant cry; Reliability; Acoustic analysis

1. Introduction

For many years, acoustic analysis has been used to explore the infant cry. Infant cry research has been looking for differences between the cry of normally developing infants as well as the cry of infants with several diseases and developmental disorders. Differences in acoustic parameters have been related to disturbances of the vocal neuromuscular maturation (Lind et al., 1967; Golub and Corwin, 1982; Fort and Manfredi, 1998), to brain disorders (Sirviö and Michelsson, 1976; Fisichelli and Karelitz, 1966; Wasz-Höckert et al., 1968; Karelitz and Fisichelli, 1962), to central nervous system insults (Lester et al., 2002; Corwin et al., 1992; Blinick et al., 1971; Nugent et al., 1996; Michelsson et al., 1977; Verduzco-Mendoza et al., 2012), to various developmental disorders like hearing impairment (Möller and Schönweiler, 1999; Arch-Tirado et al., 2004; Várallyay, 2007; Etz et al., 2012) or autism (Esposito et al., 2013; Sheinkopf et al., 2012), and to genetic defects like the down syndrome (Fisichelli and Karelitz, 1966; Lind et al., 1970), morbus crabbe (Thoden and Michelsson, 1979) and the cri-du-chat syndrome (Wasz-Höckert et al., 1968; Vuorenkoski et al., 1966). Many of those studies aimed at using the infant cry as an early, non-invasive diagnostic instrument to test for various diseases by analyzing several acoustic parameters.

While differences between healthy cries and those related to disorders are already explored, only little research about the *reliability* of the infant cry has been conducted (Robb et al., 1997; Lind and Wermke, 2002; Green et al., 1998).

* Corresponding author. Address: Müllerwies 14, 65232 Taunusstein, Germany. Tel./fax: +49 6128 210 764.
E-mail addresses: tanja.etz@hs-fresenius.de (T. Etz), reetz@em.uni-frankfurt.de (H. Reetz), wegener@hs-fresenius.de (C. Wegener), f.bahlmann@buergerhospital-ffm.de (F. Bahlmann).
[1] Tel.: +49 69 798 25031; fax: +49 69 798 23774.
[2] Tel.: +49 6126 935 2913; fax: 49 6126 935 2174.
[3] Tel.: +49 69 1500 853.

0167-6393/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.specom.2013.11.006

For this study, an *episode of crying* was defined as the total period of continuous crying activity (Grau et al., 1995). In an episode of crying, an infant produces multiple *cries*. Cries are extracted from the episode of crying for analysis. In the context of infant cry analysis, we define "reliability" as the homogeneity of all cries in an episode of crying of an infant. Therefore, reliability provides information about the reproducibility of acoustic analyses when analyzing multiple cries of an infant. This becomes especially important when aiming to automatically classify infant cries, e.g., for diagnostic purposes. Here, all cries of an infant must be similar enough for a classification model to be able to predict the same (diagnostic) result for each cry. Otherwise, for one infant its cries are classified ambiguously and the infant may not be allocated to one (diagnostic) group.

Research on infant cry reliability especially lacks of studies about which *type of crying* is the most reliable one. Cry types that have often been used in infant cry research are spontaneous cries (e.g., by Wermke et al., 2002, 2011; Manfredi et al., 2009) and pain-induced cries (e.g., by Branco et al., 2007; Runefors et al., 2000; Runefors and Arnbjörnsson, 2005). For *spontaneous cries*, the researcher has to wait until the infant starts crying without intervention. Here, the cry can have various causes like hunger, mood, desires or indisposition. Often, it is not traceable which of those might be the actual cause for crying. For *pain-induced cries*, infants are recorded when they start crying due to a pain stimulus. For ethical reasons, pain stimuli are necessarily independent of the cry analysis. Vaccinations or blood withdrawals in the context of regular screenings are often used as pain stimulus. Here, the cause of the cry can clearly be related to the pain stimulus. Although pain-induced cries being assumed to be more standardized because of the known cause, they are said to be more biased due to the high energy of the cry (Thoden and Koivisto, 1980). In contrast, spontaneous cries seem to be less standardized because of their unknown reason. Which type of crying is suited best to be used in diagnostic instruments is not answered conclusively.

In this study we analyzed the reliability of healthy infant cries for spontaneous cries and for pain-induced cries. Furthermore we generated subgroups for each of these two groups. For both sub-groups, we analyzed their reliability and compared them to the full spontaneous and pain-induced group. In this paper, we provide new insights about which acoustic parameters are consistent over multiple cries of an infant. In addition, we give lead about which type of crying is most reliable and therefore might be suited best for infant cry research.

2. Method

2.1. Subjects

In this study, 68 infants were included. 268 spontaneous cries were recorded from 35 infants (14 female, 21 male). 236 pain-induced cries (after heel prick) were recorded from 33 infants (15 female and 18 male).

All infants had no complications during birth. Their age, birth weight and gestational age were without pathological findings (Table 1). APGAR scores ("Appearance, Pulse, Grimace, Activity, Respiration", (Apgar, 1953)) were documented after 1, 5 and 10 min. For all infants, the APGAR scores were 9/10/10.

All infants were found to be healthy by paediatricians at postpartum examination. They had no indication of neurological diseases or further anomalies or any diagnosis that might influence normal development. The hearing function of all infants was assessed for both ears by otoacoustic emissions. No limitation of the hearing function was found. According to paediatricians, there was no indication for an existing cold at the time of recording for all infants.

All parents of the infants were native speakers of German and gave written informed consent to participate in this study. The study was approved by the Ethic Review Committee of the Fresenius University of Applied Sciences.

2.2. Data acquisition

Infant cries were recorded with a sampling rate of 48 kHz and 24 bit digital resolution on a Zoom H2n recorder with its built-in microphone. The microphone was held about 30 cm from the infant's mouth. Recordings were made in similar environments. For each infant, one full episode of crying was recorded. Recordings started with the first cry of the infant (using the H2n's pre-recording functionality). Recordings were stopped after the last cry of an infant when there was a 15 s pause with no crying. All episodes of crying were recorded in a supine position of the infants. One recording lasted about 10 to 30 s. For acoustic analysis, single cries were extracted from the episodes of crying.

2.3. Grouping of cries by type

Participants in this study were divided into two main groups – spontaneous cries and pain-induced cries – as those two general groups are often used in infant cry analysis. For the first group (*SP* group), recordings were started when infants began crying spontaneously. None of these cries were pain-related or triggered by any known cause. To exclude causes like sleepiness, hunger or discomfort, it was assured the infant was awake, properly fed (but not right after feeding) and had dry diapers. For the second group (*PI* group), cries were recorded during the

Table 1
Statistical parameters for the subjects ($N = 68$).

Parameters	Mean	SD	Range
Birth weight (g)	3320.85	354.51	2710–4120
Gestational age (weeks)	39.25	1.24	37–42
Age (days)	2.01	0.77	1–3