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Design of an Intelligent Pillow with Maternal Temperature and Heartbeat Vibrations for Comforting NICU Infants

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Abstract

Objective: This paper aims at providing comfort to the neonates that suffer from pain due to medical interventions in the NICU, through the mediation of maternal temperature and heartbeat vibrations. **Methods/Analysis:** Here, a non-invasive solution, providing comfort through the mediation of a parent's physiological features to the distressed neonate is adopted. This is done with the help of an intelligent pillow system embedded with wireless sensing and actuating functions. The neonates will show signs of comfortness when the maternal temperature and heartbeat vibrations are transferred via the pillow. Here, maternal temperature is added in addition to the existing heartbeat vibrations. **Findings:** Neonates in NICU undergo numerous interventions ranging from a simple diaper change to a major surgery. These neonates are subjected to pain and discomfort, especially during their initial weeks of lives. Pharmacological pain relief treatments are available, but it cannot be always preferred. Hence, a non-pharmacological technique is adopted using maternal temperature and heartbeat vibrations. This work was tested with a prototype of the recording and pillow unit, which produced the expected results of recording the mother's temperature and heartbeat and transferring them as warmness and as vibrations respectively to the pillow. **Application/Improvements:** This work can be improved by developing the prototype as a market product and also adding other maternal physiological features like voice, body odour, etc.

Keywords: Intelligent Cushion, Maternal Temperature, Maternal Heartbeat Sound, Neonates and Discomfort

1. Introduction

Neonates are premature infants who are born less than 32 weeks of gestation period. The transition from a womb to the world is a big adjustment for any baby[1]. When we go through very big changes, the first thing we search for is the safety and comfort of something familiar. Premature babies cannot keep themselves warm at first, because they have not built up stores of body fat. This is why they need external warmth[2]. New-borns need to be kept warm till their temperature stabilises. There are many procedures to improve the baby's survival, but, it all leads to stress and pain. These may eventually lead to developmental impairments.

Some of the medical interventions that cause pain and discomfort to the infants are heel puncture and venipuncture; attachment and detachment of sensors for measuring physiological body signals[3,4]. Environmental factors like excessive noise and light also affect the infants[5]. These may lead to a painful condition for the infant[6,7]. It is believed that, if the pain is left untreated, it may lead to impairments in managing the pain and stress in later childhood[8,9]. There are also many methods that are non-invasive[10].

Some physiological responses of discomfort has increased heart rate, increased respiratory rate, increased or decreased blood pressure, and decrease in oxygen

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saturation, vagal tone and skin temperature[11]. The baby is smoothed and comforted by mother's familiar heartbeat, temperature, her smell and sound of her voice[12–14]. Music is also proved towards healing of the premature babies[15]. The mother's gentle touch and breathing also stimulates the baby's growth[16].

This paper is organised as follows. Section 2 provides existing methods and various strategies in the literature related to hardware and its implementation. An outline on the proposed methodology is dealt in section 3. The hardware setup and its outputs are discussed in section 4. Section 5 concludes this paper with a future work

2. Pharmacological Treatments

There are many pharmacological pain treatments proposed in the past two decades. But, nowadays, non-pharmacological treatments have become popular and effective. Some of them are: Non-Nutritive Sucking: This was the first technique introduced as a non-pharmacological method. A sweet solution of sucrose is injected into the cheek of the infant through a syringe. This distracts the infant to suck something sweet. A pacifier can also be given during painful procedures.

Facilitated Tucking: In this procedure, the caregiver holds the baby with one hand on its head and the other on its body/feet, depending on how comfortable it is. This aims at providing a position similar to how it was in the mother's womb. It also restricts the movement space.

Skin to Skin Care (Ssc): It is also known as kangaroo care. In this, the infant is held to the bare chest of the mother and wrapped by a cloth to provide warmness to the infant. But, this is not always possible since some neonates cannot be taken out of the incubator due to some -serious medical conditions[17].

3. Prototye Design

The Proposed work describes how the discomfortness of a neonate could be reduced. This is possible when the neonate is cuddled in the warmth of the mother. This section includes the detail description of block diagram of the recording unit and the Pillow unit for comforting NICU Infants.

3.1 Recording Unit

The recording unit uses DS18B20 temperature sensor. By holding this sensor, the body temperature is sensed. The heartbeats are sampled using a heartbeat sensor named pulse sensor. There is a sample initiate button. Only when this button is pressed, the sensor starts collecting the samples. These analog samples are fed to an Arduino Mega 2560 microcontroller. It has a built-in ADC that converts the analog samples into digital values and sends it via Bluetooth HC05 to the pillow unit. Figure 1 shows the block diagram of the recording unit.

3.2 Pillow Unit

The pillow unit uses LM35 temperature sensors for sensing the incubator temperature and the temperature in the pillow. The heating unit has a heat transistor that provides the heat to the ultra fabric inside the pillow. The microcontroller used here is Arduino Uno. The heartbeat samples received via Bluetooth are amplified and given to a speaker that produces vibrations. Figure 2 shows the block diagram of the pillow unit.

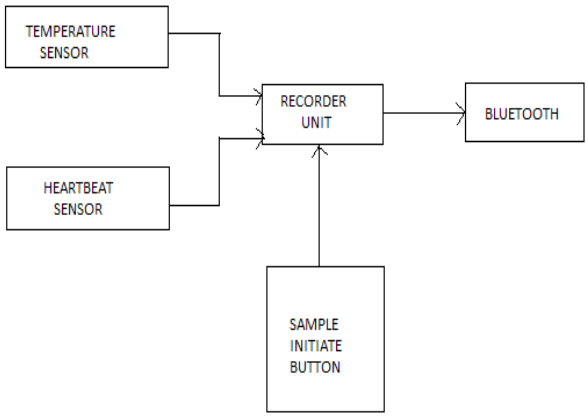

Figure 1. Block diagram of the Recording unit.

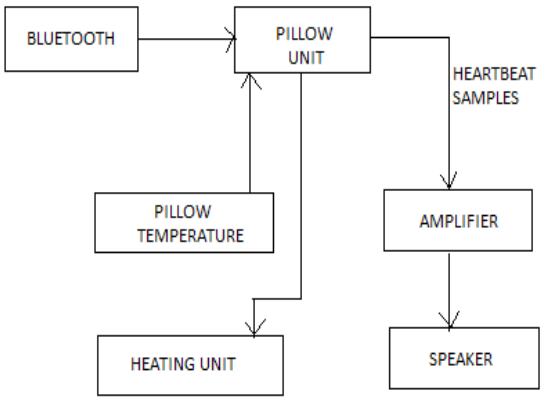

Figure 2. Block diagram of the Pillow unit.

3.3 Working

Here, in this work, we have proposed the concept of transferring the maternal features like the maternal temperature and the maternal heartbeat vibrations via an intelligent pillow. A recording unit containing the temperature sensor and the heartbeat sensor samples and records the temperature and the heartbeat respectively. These data are transmitted to the pillow unit via a wireless communication like Bluetooth. The pillow unit can be turned on and off when needed. An Arduino microcontroller is used as a controller with in-built ADC[18]. An LCD is used to display the recorded maternal temperature and heart rate as well as the incubator temperature as a feedback. A heating pad is used to produce the warm temperature through a heat transistor. Another temperature sensor is used which gives the feedback about the incubator temperature. It throws an error in case both the maternal temperature and the incubator temperature equals. The pillow is an intelligent mimo pillow that easily spreads the air inside it. It is anti-allergic, ultra-hygienic and prevents the risk of suffocation. This is an effective method which provides comfortness to the neonate under pain.

The sensor used to sample heart beats is from pulsesensor.com, which is an open-source sensor. The open source library from pulsesensor.com has been modified for our requirements to get interval between the beats and sampled values for every 2ms. This sensor works on the principle of photoplethysmography, used to measure blood volume changes. The output from the sensor is fed to an analog pin of Arduino, where the amplitude of output is measured every 2ms. A pulse is detected when the signal amplitude reaches a threshold value. Then the beat is recorded until the output falls below the threshold value. 9 more samples are recorded similarly and the interval is estimated as well as frequency of beats. Temperature from the temperature sensor is recorded for a period of time, and average value is calculated (since temperature varies in points, we take average of readings. Upon user confirmation, these samples are sent to the pillow unit via Bluetooth. Based on the interval between the beats, the heart beats are reconstructed, which is analog signal. They are sent to amplifier via analog pin later they are amplified and fed to the speaker, whose diaphragm acts as the vibrating unit. The temperature inside the pillow is measured by using a temperature sensor which is fixed inside the pillow. The received temperature value is compared with the pillow unit, if difference is greater than 0, the heating pad inside the pillow is powered up for certain time (t) and turned off. Now both temperatures are compared again, based on difference the heating pad is powered on. The time t is calculated based on the difference between received temperature and pillow temperature. Higher the difference, higher is 't' value. This process repeats until pillow reaches the sampled temperature. Later the pillow temperature is tested periodically to maintain the temperature.

Figure 3. shows a person recording her heartbeat into the recorder. Figure 4. shows a person feeling the heartbeat vibrations and the temperature.

3.4 Block Diagram

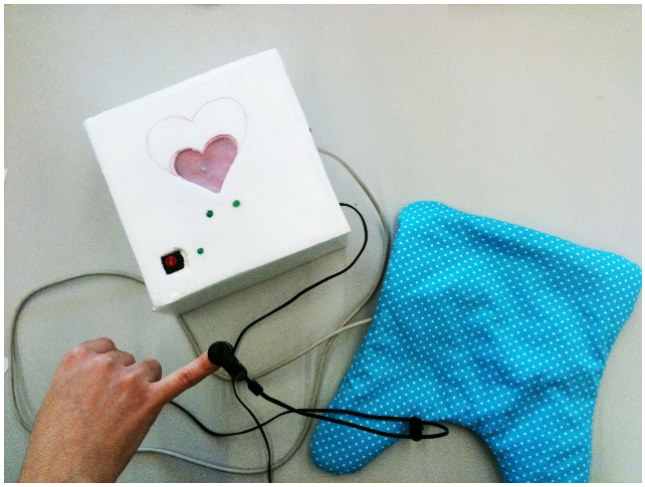

Figure 3. Intelligent pillow with recorder.

Figure 4. Feeling the heartbeat vibrations.

4. Results and Discussion

The recording unit has a heart rate sensor, temperature sensor to sample the mother's heart beat and temperature. The recording unit takes samples at regular intervals and transmits it to the pillow unit where they are reproduced. The temperature and heart rate data are transmitted using Serial Bluetooth modules (UART). At the sampling side, the pulse sensor signal pin is sampled at regular intervals to detect heart beats and calculate the heart beat rate in beats per minute (BPM). The temperature and the heart rate are sampled for 15 seconds from the mother through the respective sensors and the calculated values of temperature and heart rate are sent to the pillow unit. Here, the heating unit (heating pad) in the pillow tries to maintain the temperature of the pillow to that of mother/sampled value. Temperature maintenance is done using another temperature sensor which is fixed inside the pillow that acts as feedback sensor. The pillow unit first checks for the initial temperature in the pillow, if pillow temperature is low, it heats up the pillow for specific period based on the difference. Pillow temperature is regularly monitored and compared with received temperature to maintain close enough. Incase received temperature is very low than the temperature inside the incubator, the pillow unit throws an error and aborts the operation. The sampled heart beats and heart beat rate received from the recorder unit are converted into analog signals, amplified and fed to a speaker which acts as the vibration unit. The pillow unit can be turned off from the recorder side for safety reasons. Figure 5. shows the screenshot of the prototype of the recording unit. Figure 6. shows the screenshot of the prototype of the pillow unit.

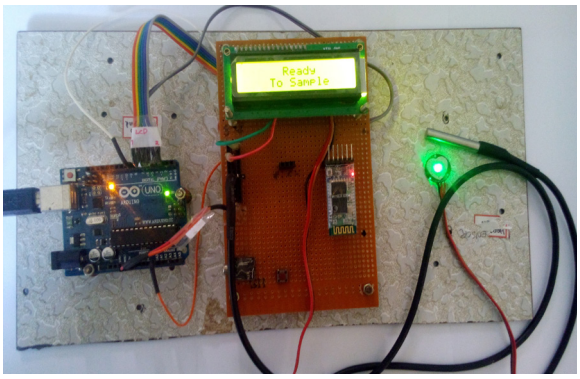

Figure 5. Screenshot of the recorder unit.

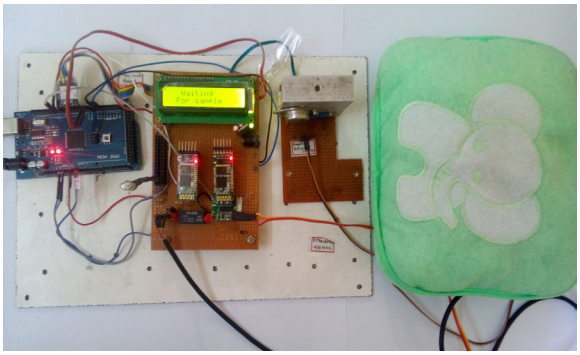

Figure 6. Screenshot of the pillow unit.

5. Conclusion and Future Work

This paper presents the design and prototype of an effective mediation of the mother's presence to the neonates in the NICU via the maternal physiological features. This paper aims at providing comfort to the neonate that is distressed in the NICU. It makes the neonate feels its mother's closeness, with the help of the intelligent pillow. This device, if designed in the market, has the capability to be safe, simple and less expensive; thus comforting the neonates. In future, other physiological features of the mother like voice of the mother and also the body odour of the mother could be mediated through advanced technology. Additionally, the neonate's ECG, EMG and heart rate variability can also be measured and recorded for further reference.

6. References

1. Brangui S, El Kihal M, Salih-Alj Y. An ergonomic comprehensive system for monitoring and control of baby environments. 2015 6th International Conference on Information and Communication Systems (ICICS); 2015 Apr. p. 251–6.
2. Sumathi OM, Malini M, Vikram T. Wireless data acquisition system for vital sign monitoring of neonates. 2014 International Conference Computer and Communications Technologies (ICCCT); 2014 Dec. p. 1–4.
3. Lu G, Yuan L, Li X, Li H. Facial expression recognition of pain in neonates. International Conference on Computer Science and Software Engineering; 2008 Dec. p.756–59.
4. Mukhopadhyay J, Saha B, Majumdar B, Majumdar AK, Gorain S, Arya BK, Bhattacharya SD, Singh A. An evaluation of human perception for neonatal cry using a database of cry and underlying cause. 2013 Indian Conference on Medical Informatics and Telemedicine (ICMIT); 2013 Mar. p. 64–7.

5. Chittora A, Patil HA. Data collection and corpus design for analysis of nonnal and pathological infant cry. Oriental COCOSDA held jointly with 2013 Conference on Asian Spoken Language Research and Evaluation; 2013 Nov. p. 1–6.
6. Mansor MN, Rejab MN, Syam S. AR model for infant pain anxiety recognition using Fuzzy k-NN. Instrumentation and Measurement, Sensor Network and Automation (IMSNA), 2012 International Symposium. 2012 Aug; 2:374–6.
7. Stevens B. Premature infant pain profile: Development and initial validation. Clinical Journal of Pain. 1996; 12 :13–22.
8. Ballesté AM, Marsal JC, Solanas A, Casino F, Martinez G. An autonomous system to assess display and communicate the pain level in newborns. Medical Measurements and Applications (MeMeA). 2014 IEEE International Symposium; 2014 Jun. p. 1–5.
9. Pitti A, Kuniyoshi Y, Quoy M, Gaussier P. Explaining neonate facial imitation from the sensory alignment in the superior colliculus. 2013 IEEE Third Joint International Conference on Development and Learning and Epigenetic Robotics (ICDL); 2013 Aug. p. 1–2.
10. Carbajal R. Nonpharmacological treatment of neonatal pain. Neonatal Pain; 2008. p. 83–97.
11. Mansor MN, Jamil S, Rejab MN, Jamil HSM. Neonates suffocated recognition based on LDA algorithm. Instrumentation and Measurement, Sensor Network and Automation (IMSNA), 2012 International Symposium. 2012 Aug; 2:352–4.
12. Michael PD. Method and apparatus for reproducing heart sounds [Internet]. [Cited 1998 Mar 18]. Available from: http://www.google.tl/patents/US5971936.
13. Chen W, Oetomo SB, Tetteroo D, Versteegh F, Mamagkaki T, Pereira MS, Janssen L, Meurs AV. Mimo Pillow - an intelligent cushion designed with maternal heart beat vibrations for comforting newborn infant. IEEE Journal of Biomedical and Health Informatics. 2015 May; 19(3):1–8.
14. Sullivan RM, Toubas P. Clinical usefulness of maternal odor in newborns: soothing and feeding preparatory responses. Biology of the Neonate. 1998; 74:402–8.
15. Butt M, Kisilevsky B. Music modulates behaviour of premature infants following heellance. The Canadian Journal of Nursing Research Revue Canadienne de Recherche en Sciences Infirmières. 2000; 31:17–39.
16. Doheny L. Exposure to biological maternal sounds improves cardiorespiratory regulation in extremely preterm infants. Journal of Maternal-Fetal Neonatal Medicine. 2012; 25:1591–4.
17. Johnston C, Filion F, Campbell-Yeo M, Goulet C, Bell L, Mc- Naughton K, Byron J, Aita M, Finley GA, Walker C D. Kangaroo mother care diminishes pain from heel lance in very preterm neonates: A crossover trial. BMC Pediatrics. 2008; 8:1–13.
18. Design of the temperature measurement system based on arduino board [Internet]. [Cited 2015 Jul 17]. Available from: http://circuitdigest.com/microcontroller-projects/arduino-humidity-measurement.