

MIMO Pillow- An Intelligent Cushion Designed With Maternal Heart Beat Vibrations for Comforting Newborn Infants

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ABSTRACT: Premature infants are subject to numerous interventions ranging from a simple diaper change to surgery while residing in Neonatal Intensive Care Units (NICUs). These neonates often suffer from pain, distress and discomfort during the first weeks of their lives. Although pharmacological pain treatment often is available, it cannot always be applied to relieve a neonate from pain or discomfort. This paper describes a non-pharmacological solution, called Mimo, which provides comfort through mediation of a parent's physiological features to the distressed neonate via an intelligent pillow system embedded with sensing and actuating functions. Clinical tests at Maxima Medical Centre in the Netherlands show that among the 9 of 10 infants who showed discomfort following diaper change, a shorter recovery time to baseline Skin Conductance Analgesimeter (SCA) values could be measured when the maternal heartbeat vibration in the Mimo was switched on and in 7 of these 10 a shorter crying time was measured.

KEYWORDS: Premature neonates, MIMO, SCA, maternal heartbeat.

I. INTRODUCTION

Preterm birth also known as premature birth is birth of the baby at less than 37 weeks gestational age. These babies are known as premature neonates. This preterm birth is the most common cause of death among infants worldwide. Globally, 15 million babies are born preterm every year and this number is rising. These premature neonates undergo several problems right from small treatment to the change environmental conditions. Some of these problems can be given as Infection – A premature baby might not be able to resist certain infections. For its own protection the baby is placed in an incubator to provide protection against these infections. If preterm labor is identified and is inevitable, there are medications that can be given to the mother to help reduce the risk of severe intracranial haemorrhage in the newborn [1]. Inability to maintain body heat – A premature baby is born with little body fat and immature skin, which makes it harder to maintain body heat. Treatment involves incubators to provide warmth. There are several complications for the premature neonates through which they are stressed. The attachment and removal of sensors required for measuring physiological signals can also be unpleasant, stressful and painful [2]. Although pain treatment is given in some of these cases, a large proportion (50%) [1, 3] of the interventions are performed without any form of pain treatment. Simple procedures and environmental factors are also possible sources of pain and discomfort to preterm neonates. Nociception is the term used to refer to the neural processes of encoding and processing painful stimuli. In preterm neonates this nociceptional system is not yet fully developed. A possible consequence of this not-fully developed nociceptional system is that stimuli such as sound and light, which are normally not considered painful to a human being, may be perceived as painful by the preterm neonate [4]. Injuries, but also clinical procedures, will result in more widespread sensitivity to pain [5]. The stay of a preterm infant in the incubator is negatively influenced by stress (excessive light and noise) and painful procedures [6]. Exposure to repetitive pain, stress and discomfort in premature infants is associated with cognitive and neuro developmental

impairments [7]. The consequences of untreated procedural pain in neonates can be both severe and long term. It is believed that exposing preterm neonates to pain negatively affects their ability to cope with pain and stress in later childhood [5, 8]. There is growing awareness that pain following a painful procedure should be treated appropriately and adequate soothing by parents or nurses is advocated. Neonates show many different responses to pain and stress. These responses can be of both physiological and behavioural nature, and can be used to detect discomfort of a neonate. Physiological responses include an increased heart and respiratory rate, increased or decreased blood pressure, decreased oxygen saturation, vagal tone and skin temperature. Behavioural responses are even more varied. Examples include vocalizations like crying and whimpering, facial expressions like grimacing with eyes squeezed shut or a stretched open mouth, and body movements like finger and toe splaying and trunk arching [5, 9]. It is worth noting that a change in any of these responses does not always imply that the neonate is experiencing stress or discomfort. Several pain-scoring systems have been developed to aggregate the behavioural signs, providing a reliable and structured tool for pain measurement. The past two decades have seen an increase in interest in neonatal pain treatment [8]. Pharmacological solutions remain popular and are the most used method for pain treatment. Non-pharmacological methods of providing comfort and pain relief do exist and some have proven to be effective. The most popular techniques include: non-nutritive sucking, offering a sweet solution, facilitated tucking and skin-to-skin care. Non-nutritive sucking was one of the first non pharmacological comforting techniques to be studied and refers to offering a pacifier for the neonate to suck on [12]. A sucrose solution can be provided as an extra means of comfort during more painful procedures. A syringe is used to gently squeeze some sucrose on the inside of the neonate's cheek. A pacifier is offered after the delivery of the sucrose, distracting the infant with something sweet to suck on [13]. One of the most successful comforting techniques is skin-to-skin care (SSC), otherwise known as kangaroo mother care [16]. Other comforting techniques include presenting the neonate with an audible heartbeat [17] or music [18] and aromatherapy [19]. If possible, breastfeeding can also be used as a non-pharmacological comforting technique, although its effect was demonstrated on term neonates [20].

II. DESIGN CONCEPT

A. USER STUDIES

Neonates can be comforted in two ways: by providing an active comforting treatment, or by taking away sources of discomfort. The fragile neonates are taken out of the incubator only for medical treatments. The care policy focuses on limiting external stimuli to the neonates as much as possible. Noise and light levels are reduced to absolute minimum and parents can visit their babies during fixed visiting hours. These hospitals also encourage the parents to take part in their child's care, by changing diapers or bottle feeding. This kind of involvement also helps the parents who often feel that they cannot help their fragile baby during the stay at the NICU. These hospitals encourage kangaroo mother care as a means of comfort and bonding. Nurses and parents from these hospitals stated that infants are the most relaxed during kangaroo mother care. Although it is clear that parents can play an important role in the comfort of their child, they cannot be present at all times to provide this comfort. In all hospitals, some more than others, there are situations in which alternative means of comforting are required. Therefore, it seems appropriate that a new comforting solution would focus on providing a neonate with the same feeling of comfort that parents would provide, even when the parents cannot be physically present.

B. CONCEPT

Based on the user studies and literature reviews we have tuned our emphasis on comforting the neonates to the extend where the safety is also ensured. Thus the concept of mimo takes into action. Since neonates show less stress signs when they are in contact with their parents and held to their chest, which seems to be one of the most pleasant experiences for a preterm neonate, Mimo aims at providing a comforting solution with qualities similar to those of being held to a parent's chest, available especially when the parent cannot provide the comfort him- or herself. This concept might not only increase the general comfort level, but it can also contribute to the bonding between parent and infant. Mimo gives parents the chance to record their personal features such as heartbeat, smell and temperature, which can be mediated to the child when it is in need of

comfort. When the concept is fully realized, the child might experience a feeling as the parents were close to them, even when the parents are not physically there. One of Mimo's basic characteristics is its ease of use, which enables parents to record their physiological features without guidance.

III. PROTOTYPE

The initial prototype of Mimo was designed to mediate the parent's heartbeat by means of vibrations, much like a pulse. One of the basic characteristics of the concept is that Mimo should be easy to set up and use, so that parents could record their physiological data on their own, without the guidance of a nurse. Then, the nurse needs only to switch on and activate Mimo when comforting is needed. Moreover, the Mimo prototype features a pillow-like device to convey the heartbeat, which can replace the regular pillows that are used in incubators, thus sustaining the neonate's environment and avoiding extra special equipment that would load the incubator. This prototype was designed to be comfortable and ergonomic for a premature neonate, but also washable and clinically safe to meet hospital standards. Options for reproducing heartbeats both in terms of sensing and output/actuation have already been explored [17]. Moreover, the main objective of our research is to develop a device that would provide comfort both to the child and the parents by empowering parents to make active contribution even when they are not present to their baby.

The Mimo prototype consists of two parts:

- 1) A mother unit (Mimo Recorder), for registration of the parents physiological features.
- 2) A child unit (Mimo Pillow), for transmitting the parent's features to the neonate.

A. MOTHER UNIT

1) Sensor

The heartbeat sensor which is an optical sensor that measures a person's pulse. Heart beat sensor is designed to give digital output of heart beat when a finger is placed on it. When the heart beat detector is working, the beat LED flashes in unison with each heart beat. This digital output can be connected to microcontroller directly to measure the Beats Per Minute (BPM) rate. It works on the principle of light modulation by blood flow through finger at each pulse. An infra-red LED on one side of the sensor shines through the finger onto a photosensitive sensor at the other side of the finger. The amount of blood that flows through the finger influences the amount of light that reaches the sensor, hence providing information about the person's pulse.

2) Electronics

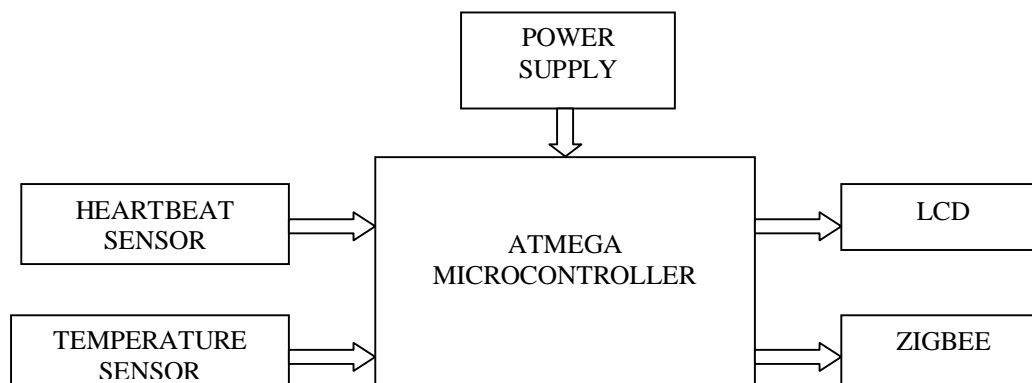


Figure 1:Block diagram for Mother unit

An overview of the circuitry inside the Mother unit can be found in Figure 1. The heart of the Mother unit is the Atmega microcontroller, powered by a 9V battery. The Atmega handles almost the complete recording process, ranging from sensing and storage to transmission of the heartbeat to the zigbee.

3) User Interface

The user interface of the Mother unit was designed to be as simple as possible, so that parents can perform the complete recording process themselves. The Heartbeat pulses and temperature from the sensor are recorded first and then transmitted using the zigbee. The output will be displayed in the LCD screen based on the following conditions.

- For pulse range below 12, the motor and the sensor will be in off state and LCD will display the output as "HEARTBEAT ABNORMAL".
- For pulse range between 12 to 15, the data is transmitted through zigbee to the child unit and after processing, both the vibration sensor and motor is switched on and LCD will display the output as "HEARTBEAT NORMAL".
- For pulse range above 15, the alarm will be blown and LCD will display the output as "HEARTBEAT ABNORMAL".
- For temperature range below 36, the motor and the sensor will be in off state and LCD will display the output as "TEMPERATURE LOW".
- For temperature range between 36 to 37.5, the data is transmitted through zigbee to the child unit and after processing both the vibration sensor and motor is switched on and LCD will display the output as "TEMPERATURE NORMAL".
- For temperature range above 38, the alarm will be blown and LCD will display the output as "TEMPERATURE HIGH".

B. CHILD UNIT

1) Electronics

Much like the Mother unit, the child unit is controlled by an Atmega microcontroller. This Atmega version is much smaller and flatter than the one used in above section, such that it is hardly felt from the outside of the pillow. Other efforts to ensure that electronics are not felt by the neonate have been made by using a specialized flat model racing battery as power supply, a tiny vibration motor to mediate the heartbeat vibrations.

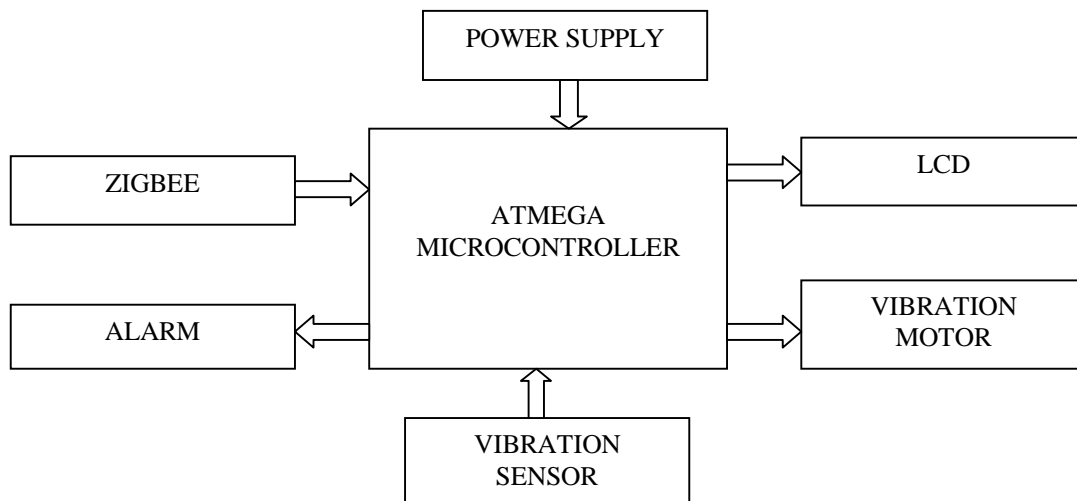


Figure 2: Block diagram for Child unit

2) User Interface

The user interface of the child unit is also made in a simple way such that, the child will be comforted when placed upon the pillow.

- When the heart beat pulse of the mother lies in between the range(12-15) beats, the motor starts vibrating and it's vibration on the pillow reduces the pain, distress and discomfort that are caused to the neonates through the external factors.

- When the temperature suitable for the neonates is achieved on the mother side, is then transmitted through ZigBee to the child side and the motor starts vibrating by giving a warm temperature to the neonates providing a feeling of comfort as they are with their parents. This also creates a bonding between the parents and neonates.

IV. RESULTS

None of the neonates showed signs of increased stress due to the pillow's presence. In addition, some neonates showed positive responses to the pillow's presence. MIMO recorder containing heart beat sensor and temperature sensor provides the maternal pulses and a warm temperature to the new born infants through the pillow so as to reduce their pain and discomfort. The vibrations made in the pillow comforts the neonates with the feeling of being with the parent.

The below table shows the temperature ranges:

S . n o	Temperature sensor range	Normal room temperature	Neonatal temperature range	Temperature given in the kit	Result/output
1	-55° to 150° C	25 ° C	36.5° to 37.5 °C,	36° to 38° C	Motor starts vibrating
2	-55° to 150° C	25 ° C	36.5° to 37.5 °C,	<36° or >38° C	Motor is in idle state.

V. CONCLUSION

This paper presents the design, implementation and evaluation of a new, non-pharmacological comforting solution for preterm neonates. Mimo, aims at comforting a neonate by providing the baby with a feeling similar to that of being close to a parent. An intelligent pillow system was implemented with embedding sensing and actuating functions for the transfer of maternal heart beat into the pillow and playing the pulsation and providing a warm temperature to the neonate through the temperature sensor. In a small pilot study, we found that the response of the infant was positive. Finally, parents and hospital staff who interacted with Mimo during the pilot study regarded Mimo as a very promising concept that would possibly not only comfort premature neonates, but also help parents bond with their infant. Thus this device has potential to be a simple, effective and safe intervention for comforting newborn infants.

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