



## Redesigning the Common NICU Incubator: An Approach Through the Emulation of Factors Resembling the Mother's Womb

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### Abstract

Incubators are essential medical devices in Neonatal Intensive Care Units (NICU) with the purpose of regulating and maintaining the required humidity and temperature for neonates and preterm infants (PI): basic survival functions. Nonetheless, their optimal development must consider other fundamental factors such as positioning of the body, orientation in space, and other stimuli. The aim of this study was to compare the emotional visual impact variation caused by the common NICU incubator and a redesign proposal that takes into account all the factors previously mentioned. The emotional impact caused by these two devices was measured through a survey using PrEmo Tool©. The results showed that through the redesigned proposal, a higher positive response was achieved while decreasing its negative emotional impact. The proposal's aim for improvement was achieved through the emulation of the mother's womb both in form and function.

**Keywords:** NICU Incubator; Preterm Infants; Kangaroo Position; Stimuli; Redesign; Emotional Impact

### Introduction

In Mexico, around two million children are born every year, of which 10 percent are premature [1]. According to the World Health Organization, prematurity is the leading cause of death during the first four weeks of life and the second leading cause of death among children under five years of age. This is an issue not only in Mexico but worldwide. Its relevance relies on the fact that the United Nations considers among its global goals to end all preventable deaths under five years of age [2].

Incubators are essential medical devices in the Neonatal Intensive Care Units (NICU) whose purpose is to regulate and maintain the required humidity and temperature for newborns and preterm infants (PI). It is said that an infant is premature when it is born before 37 weeks of gestation [3]. With the main user of incubators being the latter, it is understood that they need specialized medical care and must remain in incubators until their organs can function properly. However, NICU only ensure their survival and not their optimal development. The abrupt change of environment suffered by PI after birth should be mitigated, having in mind that they still had a few weeks left in the womb until their gestation period was complete. This can be achieved by also contemplating other primordial factors such as the positioning of the body and stimuli of sound.

### Preterm infants positioning

Due to immaturity, PI often lack adequate muscle tone and are at risk for developing abnormal movement patterns as well as skeleton deformation [4]. Proper position of premature infants may promote normal motor development while minimizing the development of abnormal movement patterns.

The positioning of PI includes supine, prone, side-lying, and head up tilted positions. Many studies have demonstrated a variety of outcomes, both positive and negative, affected by different body positioning of PI [5]. Newborns are born with a convex c-shaped spine so their thighs naturally pull up towards their chests. Laying them flat stretches out their natural position and can be stressful on their spines and hips [6].

However, the recent introduction of the Kangaroo Care© method has presented numerous benefits for the care and development of PI. Amongst these benefits, it was found that the kangaroo position, also called fetal position, is presumed to be the most optimal after its comparison with the other positions previously mentioned. The flexed position adopted during kangaroo position allows easier food digestion and breathing since less oxygen pressure and volume are required: as a result, the energy and calories of the PI are instead devoted to their own growth [6].

## Sound stimulation

Furthermore, it is well recognized that low-frequency maternal sounds, such as the mother's voice and heartbeat, are audible inside the womb early in gestation. By 25–26 weeks' gestation PI can already perceive and respond to sounds in their environment. When a premature birth occurs, the low-frequency maternal sounds in the amniotic environment are replaced by loud background noises [7]. Exposure to maternal sounds may, therefore, be crucial for healthy fetal development.

In the neonate, loud noise has been associated with hypoxemia and altered behavioral responses or cardiovascular symptoms. Noise can also have long term consequences for the newborns, by interfering with their psycho-biological balance resulting in the disruption of their normal growth and development. Additionally, it can cause sleep disorders and interfere with circadian rhythms [8].

Music is a non-pharmacological method used to reduce pain and stress in preterm in NICU [7]. The Original Sound© is a track created by a multidisciplinary group of neonatologists, pharmacologists, sound engineers, and artists. It includes a series of sounds that fetus experience during intrauterine life such as female and male voices, footsteps, electrical noises, traffic noises, TV and radio output, etc. Its use generates positive effects demonstrated by the regulation and reduction of heart rate, rise in oxygen saturation and improvement on behavioral state [7].

It is of high importance that physiological factors such as heart rate, body temperature, blood pressure, respiratory rate, and the circadian rhythm are stably preserved since the newborn's effort to self-regulate can increase the risk of tachycardia, bradycardia, increased intracranial pressure, and hypoxia. Therefore, it is essential that PI are relaxed and in a stress-free environment at all times to canalize energy expenditure for their growth and development.

NICU incubators are products that, to some degree, have an unpleasant emotional impact and this is generally not taken into account in the design of these products. Instead, they are designed on the basis of demands predominantly related to the user's survival contemplating only the basic needs previously mentioned. This proposal seeks to improve the visual and emotional impact, perceived by parents, through the emulation of the mother's womb both in form and function.

## Materials and Method

53 middle and upper social class mothers from the city of Guadalajara, Mexico, ranging between 20 and 55 years of age were asked to answer an online survey. The survey used PrEmo Tool© to evaluate the emotional impact our design proposal generated. PrEmo© is a unique, scientifically validated tool to instantly get

insight in consumer emotions. People can report their feelings towards a product whether they are positive or negative with the use of expressive cartoon animations instead of relying on the use of words [9].

Our survey consisted of 28 questions, each respondent answered it individually. First, it showed two pictures of a common incubator, the first one was the device by itself and the second one was the incubator in use. Then, the respondent had to answer some questions about how related they felt towards 14 different emotions represented by the PrEmo© cartoons. They had 3 options for each emotion: I extremely relate to this emotion, to some extent I relate to this emotion, and I don't feel related to this emotion. The cartoons were sequenced by types of emotion, showing 7 positive emotions (admiration/respect, satisfaction/approval, attraction/desire, fascination/curiosity, hope/optimism, joy/happiness, and pride/self-esteem) first and then 7 negative ones (boredom/dullness, contempt/disrespect, disgust/aversion, dissatisfaction/anger, sadness/grief, shame/embarrassment, and fear/anxiety).

After completing the first section of the survey, two pictures of our NICU incubator redesign proposal were shown. Again, the first one showed only the device and the second one showed how it would look when in use. The mothers had to answer another 14 questions in the same order as the first section.

## Results

According to the results found by the survey, it is proven that in comparison, positive emotions obtained from the Incubator redesign were more prominent than those found in the Common Incubator. Emotions such as attraction or desire were found to be more relatable for users, and fascination or curiosity had a comparably important shift.

The results obtained from the comparison of positive emotions obtained from the visual impact of the common incubator and the redesign proposal show differences in variation in the I don't feel related to this emotion as great as 17% of difference, while on the I extremely relate to this emotion answer, a difference as great as 14% was obtained. Lastly, the to some extent I relate to this emotion answer, showed a difference of variation as great as 16.3%.

On the other hand, the results found from the stimuli on negative emotions, show that the respondents overall did not relate to strong negative emotions. However, emotions such as sadness or grief along with fear or anxiety were found to be the exception. According to the data obtained by the results, when shown the common incubator, these emotions previously mentioned were found to be strongly relatable to the respondents.

In addition, the data found representing the results from the visual impact on the proposed redesign model of the common in-

incubator, stipulates that these two emotions above mentioned (sadness or grief, and fear or anxiety), had a significant variation compared to that in the common incubator.

Except from sadness or grief, and fear or anxiety, the remaining emotions did not show a comparable difference in variation and therefore, were not considered to be significant for further interpretation. The variation found on the I don't feel related to this emotion question was no greater than 5% of difference, while on the I extremely relate to this emotion question the difference was no greater than 2.5%. Finally, the to some extent I relate to this emotion question did not have a difference greater than 7.2%.

### Discussion and Conclusion

A redesign proposal was made with the purpose of mitigating the abrupt environmental change that PI go through, while improving the non-optimal positions applied in the common NICU incubators as well as the unhealthy sound exposure. In addition, it aimed to enhance the positive emotional impact caused by its aesthetics since this is a factor that is usually not taken into consideration when designing this type of products.

The results obtained from the collected data demonstrated that it is possible to achieve a more positive perception of this devices while decreasing their negative visual impact through the bio-mimesis or emulation of natural factors such as the mother's womb on the aesthetic appearance of the design. This is important since the parents' acceptance of the device is proven to come from the visual comfort that the NICU incubator should represent.

Furthermore, an important contribution from the proposed redesign includes functional aspects that would mitigate the abrupt change of the environment through the stimuli of sound following the literature proven by The Original Sound© and the recommendations following the literature of the Kangaroo Care© regarding the proper positions recommended for PI. However, further collaboration and approval from the authors of the former are yet to be obtained.

Moreover, the proposal did not aim to redesign any of the essential environmental factors needed for the proper functioning of the NICU incubator such as humidity, temperature, or oxygen. These factors are at the time, intended to be kept the same. It should be noted that the studies conducted on this project assessed the emotional impact of the common NICU incubator at one given moment. In the evaluation study of the redesign model of the NICU incubator, only one redesign proposal was tested.

A second limitation of both the first and the second study is that only the responses evoked by the appearance of the NICU incubators were measured. The experience of actually using the NICU incubator was not taken into account. In addition, the functional

implementations of the proposed redesign were based on the literature found and are yet to be tested.

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