# "Concept Car" Design Method in Medicine: Redesigning an Incubator's Mattress

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***Abstract* — When a child is born premature, he is usually placed inside an incubator in the hospital's Neonatal Intensive Care Unit. With the goal to design a new mattress for within these incubators a multidisciplinary consortium was established. In order to broaden the creative space, and, thus inspire further innovation, the design team decided to develop a controversial, but plausible incubator bed prototype through a "concept car" approach. This paper describes the process of introducing the "concept car" method into a medical setting and its effect within a multidisciplinary consortium. Through an in depth discussion and presentation of the prototype, an evaluation of the design was achieved. Questions, discussions and criticism were elicited from the consortium partners, which would serve as inspiration material for future developments within the consortium. This way of realizing ideas into a 1:1 scale prototype proved to stimulate inter-disciplinary thinking and opened doors to creativity on various levels.**

***Keywords-neonate; incubator; innovation; concept car; multidisciplinary; design.***

## I. INTRODUCTION

Within this paper, we describe the process and development of an incubator mattress design within a multidisciplinary consortium (MC) composed of neonatologists and nurses, designers, engineers and mattress developers. The method used for the development is called "concept car" design. The goal of using this design method was to broaden the creative space and thus inspire further innovation within the consortium. We describe the development of the mattress design, its effect on the creative mindscape of the MC and why we believe the design is unique in the field of neonatology.

### *A. Neonatal Intensive Care Unit*

If a child is born extremely premature, before the gestational age of 32 weeks, the child is small, fragile and most likely in a life threatening situation. In order to give the child the protection and (medical) care it needs, the child is placed inside an incubator in the hospital's Neonatal Intensive Care Unit (NICU).

Due to the, usually, unexpected child birth, sudden hospitalization of the child and stress over the uncertainty about their child's future, parents tend to experience difficulty in their efforts to bond with their child [1].

Luckily, however, in the past decades, the mortality among IC neonates has been substantially reduced by the introduction of new innovations in the fields of technology and medicine [2]. However, the long-term cognitive, neurological and behavioral developments of the neoanates are still undesirable compared to full term neonates [2].

### *B. Incubator design history*

The first incubator for prematurely born infants was developed in the year 1880 by the French obstetrician Stéphane Tarnier [4]. Inspired by incubators for chicken eggs, the main purpose of the incubator was to keep prematurely born babies warm by means of a warm water reservoir [4].

Over the years, incubator technology has come a long way. By means of new technologies and innovations in the field of medicine, infants can survive ever younger premature birth and overcome otherwise lethal diseases. However, from an aesthetics point of view, current incubators have not changed all that much. It is still a transparent "box", that, among others, keep the child warm and safe.

The reason for the transparent casing is obvious. In order to properly treat these fragile patients, nurses and practitioners should be able to observe the child. Research has, however, shown that the stimuli these children experience during their hospitalization has potential large adverse effects on the child's brain development [4][5]. Due to the large number of stressful and painful procedures, the brain of these small prematurely born babies is inhibited of proper development. Therefore, the MC has set the goal to design a new incubator mattress that will protect prematurely born babies from these adverse stimuli in the hope to ensure a more pleasant hospitalization experience by both parents and child.

### *C. Approach*

In order to spice up the creativity within the MC, the decision was made to develop a design by using the "concept car" method. Although new in the medical environment, the "concept car" method is generally used in car industry. Through a 1:1 scale prototype, car designers show the company's vision of the future in car design and inspire other designers with new ideas [6].

Our design had similar goals in mind. The main goal was to ensure the future vision of the consortium's incubator bed design would be translated and visualized into a prototype. Furthermore, the goal was to ensure that no

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innovative ideas were lost or hindered in the process. Just like a concept car in car industry will never roll over our streets, our design was not meant to be inside an actual incubator.

In order to realize our design by means of the "concept car" method, a basic, but effective design cycle of various phases (analyze, synthesize, simulate and evaluate) was initiated and was executed in 2 months.

In the analysis phase, the problems and design opportunities expressed by the various partners in the consortium were gathered. These statements were to be used as input for the synthesis phase, within which various concept designs were realized. One concept design was then realized in the simulation phase and concluded with the 1:1 scale prototype.

In order to determine whether the "concept car" method would have the desired outcome, a presentation and discussion session with all partners was prepared.

In this paper we describe the design process within which we apply the "concept car" method. We then describe the final design and the realization of the 1:1 scale prototype. Finally the evaluation of the design by the MC is presented and conclusions are drawn based upon the feedback.

## II. PROCESS

### A. *Analysis phase*

In order to identify problems and possible design opportunities, interviews were conducted with all the partners within the consortium. By discussing their desires and opportunities on future development, vital information was gathered to function as a baseline for the design. By combining this input with the consortium's original goal to develop a new incubator bed, the choice was made to focus on two main aspects within this design cycle:

1. Parent-Child bonding: specifically, the "approachability" of the child inside the incubator by parents.
2. Child comfort: the comfort of the sleeping environment for the child.

It was concluded that most of the partners found the physical acrylic transparent casing of the incubator very disturbing (it should be mentioned that as part o f the consortium there are also medical practitioners and nurses of the NICU). This physical barrier between parents and child is perceived as obtrusive and interruptive to the physical contact between parents and child.

Furthermore, the various partners expressed that it seemed unnatural to place a child that should be in a womb onto a flat mattress. Therefore, the second focus was put on the redesign of a more comfortable sleeping environment for the child. We chose specifically the sleep environment in order to provide a more open design space, relative to for instance emergency situations.

### B. *Synthesis phase*

The second stage in the design process was the synthesis phase. In this phase, various ideas are generated and developed into the final concept. Due to the diversity of design experience within the consortium, a basic technique was applied in this phase. By first developing a large number of ideas (100) in a short period of time, it was believed out-of-the-box ideas were pushed forward. From these 100 ideas, 10 different design directions were distilled by means of grouping. Every group would then be molded into a concept resulting into 10 different concepts. Finally, of the 10 concepts 3 concepts were chosen by means of ranking of which one final concept would be developed further.

The final concept, called "womb environment" (Figure 1), consists of replacing the mattress inside the incubator with an "artificial womb" in which the child would stay. Key elements within this concept are:

- To keep the child's movement restricted by presenting a flexible "womb".
- To keep the child in a warm, dark and sound limiting environment, mimicking the womb
- To provide the child with a rounded bottom of the incubator in order to ensure a swinging movement of the whole womb.

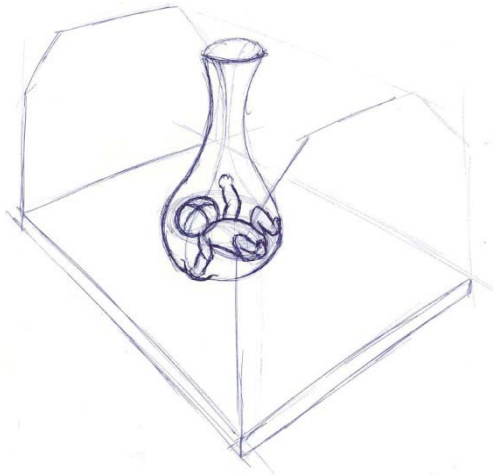

Figure 1. Womb environment concept.

Before this concept could be developed into a prototype, various small developmental cycles were introduced. During these cycles, the "womb" idea was further developed. Next we will discuss the final design as a result from these cycles.

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## III. FINAL DESIGN

### 1) CRIB

The final concept consists of two distinct products, an incubator bed and a mattress. The first product to be described is called the Child Rocking Incubator Bed or CRIB (Figure 2). This bed consists of two wooden shells that can rotate around each other by means of an elevated axis inside two side stands. This rotation allows the CRIB to be in two distinct positions.

In the first position, the child will lie on a mattress, inside the CRIB with the top shell rotated downwards, called the open position. In this situation, parents are invited to observe and interact with their child. Due to the use of wood, normally not present in incubators, the design provides a more homelike feeling expected to pull parents their attention away from the acrylic cover and more towards the inside of the incubator.

The final feature of the open position is the fact that parents can rock the bed inside the incubator, hence the name CRIB. The goal of this feature is to elicit a more natural, home-like interaction between parent and child. Just like a crib at home, parents can provide comfort to their child by means of rocking the bed. During this interaction parents can for instance decide to sing a lullaby to the child or talk to the child.

Figure 2. Closed (left) and open (right) position of the CRIB

Figure 3. Blanket over incubator

The second position possibility of the CRIB comes as a redesign of a practice performed in current day NICU's. In order to protect the child from external stimuli, such as light and sound, a blanket is nowadays placed over the incubator (Figure 3). During the design, we believed however that this blanket creates an even bigger barrier between the parents and the child, because the blanket completely restricts the observation possibility of the child inside the incubator.

As a solution to this problem, the CRIB design can be closed in one single motion towards the, so called, closed position. This will ensure that both light and sound will be restricted to the child just like the blanket. In order to provide parents and nurses the opportunity to still observe the child, a section of self-polarizing glass is implemented in the outer shell. This glass darkens by itself when light is shone onto it (like a pair of sunglasses), therefore, protecting the child automatically from excess light, but still enabling parents and medical practitioners to observe the child. Finally, the inside of the CRIB is outfitted with soft foam. This will allow the infants to push against the CRIB, just like they would experience inside their mother's the womb.

### 2) Comfort Mattress

In present day NICU's, snuggles and blankets are used in order to provide boundaries and position support for unstable babies. Especially when babies lay on their side, the limited muscle strength limits babies to maintain this posture on their own.

Figure 4. Comfort mattress

Based on the comfortable and movement restricting features of the womb, a Comfort Mattress design was proposed to be placed inside the CRIB (Figure 4).

The Comfort Mattress is an oval shaped mattress filled with silicone beads. These beads allow the mattress's shape to be flexibly molded. When the baby lies on the mattress, the silicone beads will shift and make sure the mattress adapts to the child's body shape.

Nurses are able to mold the mattress into boundaries and supports for the baby according to the baby's desired sleeping posture.

To approach the natural situation of skin-to-skin contact [7], the idea was proposed to make the surface of the mattress of a water proof, skin-like material (elastic, smooth, soft). This makes the cover easy to clean with alcohol, which saves the effort of washing the various sheets, blankets and cushions.

Wrapped in by a "skin" in a dark and rather closed sleeping environment with unobtrusive vital sign monitoring, it is expected to supply a comfortable and safe environment for premature babies within the NICU.

## B. Simulation phase

As a final step in the design phase, both the CRIB as well as the Comfort Mattress were brought together into a working physical 1:1 scale prototype (Figures 5 and 6). The prototypes contained all the materials proposed in the design

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apart from the self polarizing glass and the skin-like mattress cover. These two features were, however, clearly explained during the presentation of the design to the consortium partners during the evaluation phase.

Figure 5. Prototype CRIB and comfort mattress

Figure 6. Prototype CRIB and comfort mattress

### C. Evaluation Phase

In order to test the effect of the design, a presentation was set up for all consortium partners. The prototype was displayed in an NICU incubator together with a realistic and detailed picture presentation. By doing so, the NICU environment was recreated in order for everybody to transcend into the NICU atmosphere prior to presenting the details of the design itself.

The design was then presented through interactions with the prototype and an illustrative PowerPoint presentation. After the presentation, participants were invited to interact with the prototype, and in the meanwhile discuss the design. Finally the individual discussions were brought together in a group discussion concerning the presented design.

In order to test the effect of the design on the innovative and creative thinking of the participants, the different newly generated ideas and comments were documented and grouped together. The diversity of techniques used to generate new ideas were perceived as an indication to the effect of creativity generation among the partners.

## IV. DISCUSSION

Below the various techniques observed to generate new ideas and innovations generated during the discussion are categorized, accompanied by examples.

### A. CRIB discussion

#### 1) Taking a feature and place it in context

The first category is based upon the fact that a feature was highlighted from the design and was developed further by placing it into context. An example is the self polarizing glass. The feature was not only perceived as useful, but the possibility was proposed to use it as an active indicator of environmental light conditions to parents and medical staff. The original idea behind the glass was only to protect the child from excess light in the NICU environment. However, as commented upon during the discussion, the glass could also be used to inform parents and or medical personnel there is simply too much light in the child's environment. By doing so, they would become more aware of their environment and possibly undertake action to make it darker, hence more comfortable for the child. It was noted that this would also involve parents more in the care of their baby, giving them a foothold for something they can actively do as a means of care for their baby.

Furthermore, the function of the glass as an augmented information display was proposed. This display could indicate the health status of the baby while looking at the baby. The idea could potentially make the monitoring of the child more comprehensible for parents and more convenient for medical staff.

#### 2) Taking a feature and build upon it

The second approach observed during the discussion is to take a feature of the design and further built upon it. An example of this can be related to the closed position of the top-shell of the CRIB design. Originally intended to passively protect the baby from external stimuli like sound and light, the idea was proposed to see what other functions could be added to the top-shell itself. "It might contain sensors to monitor the child" or "light therapy LED's could be built into the shell". This shows that interaction and shape can be an inspiration in itself to those who are unfamiliar to the prior design.

#### 3) Turning critique into creativity

The third technique explains the moment where a point of concern was used as an inspiration for future innovation. One of the comments expressed by one of the medical practitioners was "that the design looked like an incubator

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inside an incubator, possibly creating an even bigger barrier between parents and their child". Although accepted by the design team this comment on itself provided inspiration for future development. Because what if the design would actually be an incubator inside an incubator? Due to its size this would mean that, if guaranteed to provide the required safety, the design could be used as a portable incubator. This would allow parents to walk around with their child inside the NICU ward, which would elicit whole new kinds of interactions between parents and their baby. It would for instance give parents much more freedom within the safety of the hospital. From a technological point of view, it would mean full wireless communication would be needed. Providing new opportunities and challenges for both designers and engineers. From this example, one can see that the physical presentation of a concept in the early stage of a design process can contribute greatly on the inspiration and development in future phases.

*4) Would this concept really work in the NICU setting?*

Apart from being nursed in the incubator, patients in the NICU may become ill and experience situations that the immediate access to the patient and institution of treatments (stimulation of breathing, resuscitation etc.) are indicated. In addition the performance of diagnostic procedures (Echocardiography, cranial ultrasound) in the incubator must be possible. In the next version of the CRIB mattress these considerations have to be taken into account.

### *B. Comfort Mattress Discussion*

*1) Where different disciplines meet – part 1*

A topic of inspiration provided by the Comfort Mattress was the fact that the designers dared to make design decisions early on in the project. For instance if we consider the Comfort Mattress, during the design process it showed innovation was hard to realize in something so common as a mattress. The "half-egg" shape of the mattress design challenges the widely accepted flat configuration of everyday mattresses.

Although the idea behind the shape was welcomed and accepted by designers and engineers, concerns were expressed by medical practitioners. The question was put forward "whether the Comfort Mattress could cause asphyxia?" Since the autonomic motor ability of premature infants is not well developed, they are unable to push the supports away by themselves. This could make breathing difficult, especially when the child is in a lateral- or prone position.

This subject, asphyxia, was pointed out as a concern from both the medical practitioner's and mattress developer's side and was not presented earlier within the project, and, therefore, not seen as a potential problem. However, due to the presentation of the design, the subject is on the table.

*2) Where different disciplines meet – part 2*

The second topic concerning the Comfort Mattress was its cover material. Nowadays, babies don't lay immediately on the mattress, but on top of cotton sheets. The proposed cover has a skin-like feeling. From design and medical points of view, the child with frequent skin-to-skin contact has a more stable heartbeat and breathing rate [7][8][9].

However, it has to be investigated whether this skin-like material has similar beneficial effects to the baby.

To prevent liquids from damaging vital sign sensors inside the mattress and be easily clean, the cover was required to be waterproof by technical and medical staff. However, medical practitioners and the mattress developer gave their concerns on this subject: can the material also be breathable?

The answer to this question is considered beyond the scope of this paper. However, if we look at the large field of material innovation, the solution probably will not be so far in the future or even already existent.

### *C. Summary*

To summarize, the overall impression of the various disciplines in the MC was quite positive. They agreed that the design contained most important elements that were gathered during the interviews. Furthermore, they believed the design is expected to elicit a better "approachability" of the child by the parents. Especially, the rocking of the bed was seen as a natural and intuitive approach of a small child.

Finally, the idea of converting a flat mattress into a 3D moldable mattress that fits the child's individual needs was seen as a great advantage. Since it has been shown that even these small patients need individualized care [10], this would further support in this hypothesis. From a design point of view the large amount of techniques used to draw inspiration from the design was perceived as successful. Since one of the original goals was to inspire future development within the MC.

## V. CONCLUSION

Within a multidisciplinary consortium the decision was made to design and build an out-of-the-box, but plausible, incubator bed to be placed inside present day NICU incubators. The focus of this design was to enhance the sleeping comfort of NICU neonates and provide support to the bonding process between parents and their child.

The final goal of the design cycle was to develop a 1:1 scale "concept car" model of the final concept. This to ensure a visual and "experiencable" prototype could be presented to the full variety of partners in the consortium.

This model was presented to the various partners in order to receive critique and develop new ideas that could be used in the future design process.

During the discussion session, new interactions were developed, features inspired new ideas, lessons were learned from decisions that had been made, and teams learned from

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each other's expertise fields. Overall, this resulted in a thorough document of delight, appraisal and criticism greatly facilitating future design and development stages.

In general, it can be said that the CRIB and the Comfort Mattress, as they are presented now, will never see the light of day in an actual NICU. This, however, was also never the intention of the design, just like concept cars in car industry never get to drive on our streets. The main goal of inspiring fellow partners by means of a physically build 1:1 scale "concept car" prototype in an integrated design solution has shown its positive impact and will hopefully be used more in the field of medical design.

## VI. ACKNOWLEDGEMENT

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