

Parents' Preferences Considering the Artificial Womb: An Exploratory Study

Iris Berden

i.berden@student.tue.nl

Stefan Groothedde

s.groothedde@
student.tue.nl

Mary Han

m.han@student.tue.nl

Frans Rijnders

f.g.r.rijnders@
student.tue.nl

Industrial Design, University of Technology, Eindhoven

ABSTRACT

The artificial womb is an emerging technology meant to create a healthy, natural and safe environment for the development of a premature child [14]. This study addresses and explores the preferences of parents considering the artificial womb to create the most reassuring and ideal experience for the parents undergoing this difficult process. By first consulting a neonatologist, certain aspects were discovered to have a substantial effect on the parental experience of having a baby in an incubator, and are perceived to have a similar effect for the experience regarding the artificial womb. To explore these aspects further, they were then implemented in semi-structured individual interviews with 11 parents who have had experience with a child in an incubator. The interview was broken in to two parts: first, asking parents about their personal experiences of having a premature baby, and second, using varying prototypes to evoke their thoughts and feelings regarding aspects of the artificial womb. The findings of the interview were clustered in to themes and validated by a neonatologist on the baby's development and medical limitations. Taking into account the preferences of parents and validation of the expert, guidelines were composed covering the topics of visibility, material, shape, physical contact, privacy, information provided and artificial connection. In conclusion, for parents to feel more confident, reassured, and less stressed about their preterm baby developing in an artificial womb, it is important to effectively show them the safety of their baby and give them the ability to display the parental care that would help their child. To create a more valuable outcome of this research, more participants should be interviewed and future research should be done on the implementation of the guidelines into the development of the artificial womb.

Author Keywords

Artificial womb; Incubator; Preferences; Open-coding; Parent-Infant relationship; Guidelines; Preterm; Viability

INTRODUCTION

Today, the chances of surviving an extreme premature birth are very low. In the current situation of the western world, preterm babies are placed in an incubator (possible from the age of 22 weeks onwards) [7]. The chances of surviving such a premature birth without life-long injuries are low, with survival rates of 0.7% at 22 weeks [46] and high rates of

morbidity [20]. Bottoms et al. [44] reported five survivors of the 26 preterms at 22 weeks of age investigated, among whom only one survived without a handicap. A baby is considered premature when it is born before 37 completed weeks of gestation (this definition is made at the Second European Congress of Perinatal Medicine [47]).

One of the main causes of death for preterm infants is the underdevelopment of their lungs [43]. The negative developmental outcomes of preterm birth, however, are not solely caused by the biological consequences of the preterm birth itself, but also by the stressful conditions following early delivery [8]. Scientists believe that, due to these stressful conditions, the clinical possibilities of the incubator (NICU) have been exhausted [21]. Therefore, an alternative approach in which the preterm infant can develop in a more natural environment is being eagerly sought after [18]. This approach takes shape in the concept of the artificial womb. The artificial womb revolves around creating a resemblance of the natural environment for a preterm infant to grow up to a state in which he can live on his own [14]. Even more: it is about pushing the limits of what we now call viability way back, to a border which is not yet known [22].

The artificial womb is a promising and fast emerging technology which can have a great positive influence on the fate of millions of these fragile infants [48]. Considering it from a technical point of view, the artificial womb has many positive effects on the health of the infants: the risks of several preterm diseases decrease, circulatory problems are less present, the risk of infection decreases, and the chances of survival for the infant increase due to, for example, the lungs of a preterm infant not needing to properly function yet in the artificial womb.

However, little research is done on how the parents experience the incubator [8] and almost no research is done on what their preferences would be considering the experience with the artificial womb. For every infant undergoing premature development, parents can have a very stressful and challenging time [26, 3, 16].

Therefore, the research presented in this paper works towards design guidelines for the artificial womb based on a parental point of view, considering the baby's development and medical limitations. The results of this study (knowing overall parent's opinion/preference on the aspects) can be

used for decision making in future development of the artificial womb.

THEORETICAL BACKGROUND

In this paper, the context of the discussed matter is in the current situation the *incubator*, with its potential successor the *artificial womb*. Before continuing to our specific research, these two objects/environments will be explained.

Incubator

The incubator, or neonatal intensive care unit (NICU), is a box-like enclosure which provides premature babies with the environmental conditions to thrive. Babies that are born prematurely in the 22-36 week period are placed in an incubator to increase their chances of survival [7]. Since developed in the 1950s, the incubator has undergone many advances in technology that have improved the ideal environment for premature babies. Microprocessors regulate the temperature, humidity, and oxygen levels inside the incubator and can even self-adjust according to the necessities of the baby. Noise levels, harsh light, allergens, and infections are also factors that the incubator protects newborns from [29].

One of the most important aspects of the NICU is that parents can have direct skin-to-skin contact with the baby through the sides of the incubator [39].

While the incubator is currently the most successful option for premature babies, there are still disadvantages such as the crucial issue of the lack of development in the lungs of premature babies, infections, and the overuse/underuse of oxygen, which can have detrimental effects on the physical and psychological development of babies placed in an incubator [38]. As a result, scientists are working to develop other methods that can create a more natural environment for a premature baby to develop in [14].

Artificial Womb

Romanis [14] gave a very detailed overview of the development and potential implications of the artificial womb. She described the artificial womb as a completely novel approach to the existing NICU that faces the challenge of the development of premature babies. Currently, with preterms facing many complications while developing in incubators, they are unable to adequately perform bodily functions in such an exposed environment. Preterms must be assisted by mechanical ventilation, which can further cripple the development of their lungs, and external circulation pumps, which can even lead to heart failure [33]. Instead of placing a preterm in the NICU, the artificial womb aims “to extend normal gestation and create the most natural environment” for the baby according to Romanis [14]. This method is groundbreaking in the way that preterm infants do not have to face the issues of underdeveloped lungs, circulatory problems, and risk of infection. One of the major issues surrounding the artificial womb is facilitating a nurturing environment in which the mother can bond with her infant. Without the possibility of skin-to-skin contact as

in an incubator, it is difficult to foster the necessary interactions between a mother and her infant that ensure a psychologically and emotionally healthy baby [42]. Researchers seek to find a solution that can provide this maternal bond for premature infants. In 2017, a research team developed an apparatus called the bio-bag which consists of a pumpless oxygenator and access to the umbilical cord [15]. The bio-bag imitates a real womb with placental circulation, supplying all the nutrients, oxygen, and water necessary for vitality. The researchers declared that the test subjects (lamb fetuses) had successfully been supported, with normal lung development and circulation without infection [14]. With the success of the bio-bag and ever advancing technology, researchers are eager to develop an artificial womb that can successfully continue fetal development and possibly work beyond the current viability threshold [22].

Themes

The preferences of parents are not yet researched upon [42], due to the artificial womb being a new technology with researchers mainly working on the engineering and healthcare part of the artificial womb. For this reason, this paper consists of the exploratory work regarding parents’ preferences. By means of an interview with a neonatologist (D.R. Kommers, personal communication, March 15, 2019) a few aspects have emerged that are present in the current parental experience of the incubator. Because these aspects are likely present in the experience with the artificial womb as well, these aspects were implemented in this study. The initial aspects that were discovered are explained below.

Visibility

The fetus is able to see in the mother’s womb upward of 28 weeks, with eyes wide open at this time [40]. Due to their underdeveloped physical and mental maturity, premature babies can show little eye contact after birth [32] making it frustrating for mothers to interpret a newborn’s communicative cues [27]. Research has shown that mothers follow the direction of their baby’s spontaneous looking, which indicates that the mother’s visual behaviour becomes synchronized with that of her infant [17]. In the current situation with the incubator, seeing their infant right after the birth lessens their fear of maternal separation [45]. It also helps developing an optimal maternal attachment [25]. These things combined show the importance for the mother to be able to have visual contact with her newborn.

Stress

Pascoe, Bissessur and Mayers [32] stated that when dealing with the high stress of an early birth and separation from their newborns, mothers feel unprepared, lose confidence and often develop maternal-depression. This high stress level can negatively impact a mother’s parenting and weaken the process of synchrony, which can ultimately have an adverse impact on infant’s brain [32]. One of the most common stressors for parents that have an infant in the incubator is the anxiety about their infant’s well-being [28]. This anxiety is represented by the presence of an alarm at an incubator: at

any moment it can start howling (light and sound), indicating a (potential) calamity [39].

Physical contact/intimacy

One method that has proven to have positive effects on maternal-newborn bonding is kangaroo care, or skin-to-skin care [10]. In kangaroo care, when mothers have physical contact with their newborns, the protein oxytocin is released in newborns as a co-regulator, which show the co-regulative process of bonding [10]. According to Feldman [41], parent-infant synchrony also occurs during bonding when the heart rate between mother and infants become the same, giving the infant an emotional sense of security. Feldman [41] has proven this synchrony can “act as a buffer against psychosocial maladjustment, lower future levels of behavioral problems, and shape an adolescent’s capacity for empathy and develop human relationships across a lifespan.”

Contact on distance

Research has shown that it is important for a mother to have the possibility to withdraw to an area distant from the newborn nursery [2]. However, maternal separation can disrupt attachment. This problem can be solved by facilitating maternal proximity by showing her pictures of her baby shortly after the birth [6]. In addition to this, the caregiver should inform the mother about the incubator environment, by showing video presentations and telling what to expect when visiting this department. Informing the mother will decrease her stress and hopefully improve maternal-infant interaction. In addition, there are products on the market which simulate pregnancy on the body, e.g. a dress that uses warm water to mimic the fetus, or vibrators to simulate kicking [9]. However, these products can give more discomfort rather than providing the comforting feeling of being pregnant.

METHODOLOGY

Triangulation of sources and examining different sources of data through interviews was used to support this study [31].

Conversation with Expert

First, a conversation with D.R. Kommers was held to create a better understanding of the NICU, incubators and the possibility of having an artificial womb in the future. Because of this conversation, the researchers were able to set up general themes which seemed to have a substantial impact on the parental experience and were important to explore in the upcoming interviews with parents. The themes which came up the most in the conversation and seemed to hold the most importance were: bonding and physical contact between the parents and their child, parental stress, knowing their child is safe, the transparency of the artificial womb, alarms in the NICU and additional products and services which help parents stay connected to the baby at a distance.

Interview with Parents

Second, the interviews with 11 parents were conducted. The type of these interviews is a semi-structured interview [36], which focuses on interviewing individual participants using a checklist of headings to steer the discussion towards certain

design characteristics (e.g. the material of the artificial womb). This style of interviewing ensures a consistency across the sample of participants, and also leaves room for the participants to elaborate or digress.

Design

Third, the themes visibility, materials, feeling safe, and alarms were implemented in the form of variations of a prototype using different objects to remind parents of their experiences and evoke their thoughts and feelings. The main object used in each variation is a realistic model of a preterm baby of 24 weeks lying on his back. Throughout the interview the baby is surrounded by different objects to introduce parents to different situations. The first variation used in the interview is the baby inside a transparent sealed rectangular plastic bag with a small grey cap in which a tube goes through (see figure 1). The second variation uses the same baby inside a similar plastic bag, only this time the bag is white and opaque. The last variation shows the baby inside the transparent plastic bag, but the baby and bag are placed inside a closed rectangular transparent plastic box.



Figure 1. The prototype of the first variation: A model of a premature baby inside a transparent rectangular plastic bag.

Participants

The participants who took part in this study were 11 parents with experience of having a preterm baby in an incubator. They were contacted and recruited through contacts of acquaintances in various parts of the Netherlands. For the participants, the amount of time in which their child was in an incubator varied between one and eight weeks. Additionally, the number of weeks of gestation of the mother varied between 24 and 36 weeks. In order to create a more comfortable experience, the interviews were conducted at the home of the participant.

Study protocol

At the start of the interview each parent received and filled in a consent form which stated that they give explicit consent in processing their data and that they are allowed to withdraw from the interview at any moment for any reason.

Then, each participant was introduced to the artificial womb and shown an image of the lamb [33]. They were told that the artificial womb is meant to function as an incubator for preterm babies starting from 24 weeks of gestation [5]. Consequently, each participant was asked to talk about their experiences during the time their child was in the incubator. Topics to elaborate on in the interview were: different ways of connecting with their baby (at home and in the hospital), their thoughts about hospital staff, in what form information was communicated, the NICU environment, and contact with other parents and aftercare.

For the second part of the interview, the prototype of the baby within the transparent bag was placed in front of the parent. Each parent was told that this could be a simple representation of the womb, without the wires connected to the pump, the baby, and the amniotic fluid, and they were asked to react on what they saw and how they felt when seeing this prototype.

Consequently, the researcher showed the second prototype and asked for any thoughts and emotions they were experiencing. Additional questions were asked to elaborate and clarify what the parent meant, and to steer the conversation towards the design characteristics meant to be discussed.

This process is later repeated with the third prototype variation. Additionally, a flasher alarm was placed on the table next to the baby to give them a scenario of a possible alarm, and the parents were asked how they would like to be informed in which situation.

At the end of the interview, the most important points were repeated, and the researcher used co-creation by asking the parent to think about the physical form of the artificial womb and to draw or explain it to clarify what they meant.

Expert Validation

Lastly, after having coded and clustered all the interview data, draft guidelines are created from the clusters. Then the researchers had another meeting with D.R. Kommers to validate these guidelines in the development of the baby and medical limitations.

Data Collection

Presenting Extremes

The variations of the different prototypes are meant to be simplified, extreme options – the options are in itself most likely not what the participant would choose. This was done so the participants would not immediately agree with an option and were motivated to think about and explain what would fit their preferences best. In this way, the most valuable reasons behind their opinion will be obtained and the researchers can find out what the participants really find important [4]. More importantly, by presenting undesirable extremes we make sure that the research is not biased by the researchers own opinion or preference [11].

Co-creation

Co-creation consists of interacting with the participant to create a concept or solution to a problem together. This can take any shape or form, ranging from the physical to the spiritual world [13]. It is overall assumed that the direct involvement of users in the design process has a positive influence and brings significant knowledge and insight [19, 34].

In this research, the co-design method is applied in understanding the participants' preferences and opinions in the throughout the interview. For example, the researchers changed their subsequent questions according to what the participant says to gain a more in-depth understanding. This method made it possible to find out in detail the preferences each participant had of the artificial womb.

To accomplish co-design, all the interviews for this research are done face-to-face. The benefits from this approach are that we have the opportunity to use visual cues and visual aiding gestures to prompt discussion [35].

Data Analysis

The data is analyzed according to the Steps for Qualitative Data Analyses described by Terre-Blanche, Durrheim, and Painter [30]. First, the recorded interviews were transcribed from beginning to end through means of immersion. The researchers printed and read through the interviews numerous times in order to immerse themselves in the data gathered and gain a holistic, in-depth analysis. Then, open coding was used to further break down and organize meaningful instances of data. Words and phrases were highlighted and given codes that were as close to the vocabulary of the interviewee as possible. After, the different codes with the corresponding quotes were cut out and grouped. Through this process, more groups were discovered which meant that the researchers needed to go through the quotes again to ensure each quote was in the correct group. Following this process, groups were merged and comprehensive themes were made. Again, the quotes in these themes were checked to see if they corresponded correctly. These themes ultimately exhibited the major findings from the data gathered and the numerous perspectives of the interviewees [23]. So, through coding, the researchers were able to break down large amounts of data and discover interrelationships, correlations, and outliers that were present.

Ethical considerations

Bryman and Bell [1] determined the ten most important points about ethical considerations in research and dissertations. Those ten points are honored in this research. Firstly, our research consisted only of doing consensual interviews, which did not harm the participants in any way. Secondly, the full consent of the participants is obtained by giving them a consent form in which all the specifications of the interview are stated. In addition, the consent form asks permission from the participant to record the interview, explaining for what purpose it will be used. Thirdly, total

anonymity of the individual participants is ensured by using the abbreviation 'P1', 'P2', etc. when citing one. Lastly, in the paper, the primary interview data is displayed unbiasedly and verbatim to the words of the interviewees.

Reliability

Maxwell [24] determined five different kinds of validity which are applicable for this research. To ensure both descriptive and interpretive validity in this paper, both the raw data (themes) as well as the interpretation of the raw data (guidelines) are displayed. To ensure generalizability, participants from different parts of the Netherlands, having different backgrounds (religious vs. non-religious or different generations) are selected. Theoretical validity is ensured by explaining the phenomena found in the study by means of showing the validation of an experts. Also, the theoretical background of this research is ensured by underpinning every used method with various scientific sources. Evaluative validity is ensured by evaluating the results with an expert, which provides a different perspective on the guidelines composed by the researchers.

FINDINGS

In the following part, the results of this in-depth analyses of the data are shown, in the form of the different themes extracted from the interview data. For every theme, a summary of the parent's opinions is given, illustrated with direct quotes from the interview. In the following part, the themes are shown together with the expert's opinion on that specific topic.

Reason versus Feeling

Parent

Generally, parents want what is best for their child. They understand that the decisions made in the hospital are generally the best for the development of their child, but seeing and experiencing these actions might trigger protective mother instincts since their baby is distant, fragile, and underdeveloped. P6: *"It is the best for your child, but as a parent you can't always be sober."* In the end reason wins, giving the baby's development priority over their own needs, but where possible, the parents emotional needs in bonding with the baby need to be tackled.

Expert

Two things determine the feeling of stress: what the mother can do and what she wants to do. Either she wishes to be able to contribute vastly in the process of ensuring her baby's healthy and safe, or be reassured that the situation is ideally as it would be in the natural environment. Both can help in decreasing this feeling of distance and stress.

Supplemental Connection

Parent

In many NICUs today, there are cameras installed for parents to be able to see their baby from home. However, most of the parents stated they would not use this addition since it feels too impersonal and distant. P4: *'Yes there was a camera, but it felt so fake'*. Besides a camera, possible additional products

or services that give the feeling that the mother is still pregnant were rejected as well. Most parents declared that since they knew the baby was born, they would not need any form of aid that would simulate this feeling, as it would feel fake and artificial. P7: *'No because the child is out of your body. So be it.'*

Arrangement

Parent

Privacy can be possible in the environment of the artificial womb by separating each one from other newborns. P8: *"All was going well, but you do miss that... A bit of privacy"*. If the wombs are collectively in a general space, others are nearly always present and a moment of privacy for parents with their child is nearly impossible. Support, on the other hand, can be found in different ways such as institutions, doctors and other parents that have experience with premature babies. Therefore, parents prioritize private rooms over immediate support at the artificial womb, but this support has to be provided elsewhere. P2: *"If there are people that can support you, to which you can talk, that you know that isn't weird what you are feeling"*.

Expert

The opportunity for privacy in the form of a separate room is the most important. Support is possible through other ways.

Safety

Parent

According to the parents, the prototype of the artificial womb looks and feels vulnerable. Parents are afraid to touch it since they think they will damage it too easily. P5: *'I'm afraid it would leak'*. The base material must therefore represent sturdiness to give the parents the assurance that their baby is safe. An extra layer of protection would provide this sturdiness, but this layer should be removable so physical contact is possible and so the parents do not feel too distant. P11: *'If the mother is gone and they would place it in this... I would like that idea.'*

Physical Contact

Parent

One reason parents want to touch their child (mainly skin-to-skin) is because they believe it can be soothing for the child and give the child the feeling of safety. Considering the artificial womb, most parents admitted they want to be able to physically feel their child. P5: *'I really would want to feel him.'* An often mentioned reason is that they believe it would closely resemble feeling their child in a natural womb, which would bring comfort to them. P11: *'I find feeling him important because it's closer to nature.'* In addition, some parents mentioned that they miss the presence of the baby in the womb and therefore would want to be as close to the child as possible. Unfortunately, due to the sealed encasing of the artificial womb, no one can have skin-to-skin contact with the baby, which some parents expressed pity. P2: *'Can feel my kind less than with kangaroo care. Skin-to-skin contact is anyway very important.'* Knowing the constraints of the

artificial womb, the parents prefer to feel their child through a soft material over a hard material. Regardless, the parents greatly stress the priority of the safety of their child despite their own needs and desires. P9: *'I only would want to touch the child when I know that it is good for the child.'*

Expert

Physical contact may not be needed any more if the parents know that the child's wellbeing is prosperous. In the incubator the skin-to-skin contact is necessary since the child and parent are both stressed. However, in the artificial womb the child will not experience this stress because his environment will ideally be a reflection of the natural environment in his mother. It is, on the other hand, important that the parents are relieved from this stress as well.

Parent-Infant Relations

Parent

Many mothers express their desire to be the best mother they can be while their child is in the artificial womb and to nurture the bond with their child as best as possible. P4: *'I want to be there for my child on any way possible'*. The best experience for a mother is when the baby truly recognizes her. Most parents also mention that they want to enhance this parent-child relationship by being as close to the baby in the bio-bag as possible, preferably holding the bag. The baby then feels the heartbeat, smell, warmth and breath of the parent, which gives a feeling of safety in a natural way. P7: *'This is very good for bonding too.'*

Considering the incubator, the parents state they felt powerless, since nurses are the ones that take care of their child. Doing nothing but waiting wait is difficult. They also are concerned about the implications of the hectic environment and multiple hands touching the baby on its development. This would not be a problem with the artificial womb. P4: *'With this [the artificial womb], no strange hands or strange smells reach the baby, which is a huge advantage.'* On the other hand, the parents want to rely on the professionalism of the nurses and do not feel responsible for the medical care for their child, since they do not have expertise in that area. In this, the parents mention their disapproval of how the communication is done when moving the baby to another hospital. Without the contribution of the parents, caregivers would miss important information. P1: *'It's the world upside-down, you expect them to know everything!'*

Guidance

Parent

All parents express that their experience during the neonatal period is extremely stressful. P3: *'You experience so much tension, which later also caused depression.'* A reason for this is that the preterm birth occurs so suddenly that many do not know how to react. Most parents do not want to be alarmed because it is too stressful or even annoying. P5: *'The absence of an alarm will provide tranquility.'* All the parents agree that they should be involved when there is

something critically wrong with the baby. Some parents wish not to see everything, e.g. disconnection of the tubes, yet a few do because they want to ensure the safety and well-being of their child. P4: *'I found it pleasant that nothing was hidden.'* P3: *'I found all the bleeps reassuring, lets me know that everything is alright.'* In addition, the parents stress the importance of aftercare. Speaking with someone who understands the situation can be exactly what a parent needs when undergoing so much stress. Also, artifacts like photos of the neonatal period can be beneficial for the parents. P11: *'For the processing period of the mother, it's important that there are made photos from the exit-procedure [considering the artificial womb]'*.

Expert

Parents want to know that all is going well. This has to be represented in the environment and arrangement. For example, the absence of alarms brings forth a less stressful situation.

Visibility

Parent

Even though parents are not able to see their baby when it is inside the mother's womb, almost every parent stated they want to see their baby in the artificial womb. P7: *'No, you want to see your child. At least, I would want to see it because this is how it is. And you can fool yourself, but it is just the case.'* P8: *'Not being able to see is unpleasant for me. Because than you are completely disconnected from your child, then you just need to believe it is in there.'* Parents also find it important to see their child because it is means of connecting with their child. P4: *'No, it would be a terrifying thing for me. I think you would have a complete mourning process. You cannot see and you cannot feel. You are being replaced by a bag. Yes, I do not think I would like this. And the crazy thing is, in the womb you would not see it either. But by feeling it you create a connection.'* Some parents prefer a translucency of the material, or even the option to choose to see the baby or not. P7: *'I would do something which is partially transparent. So that you can see but not entirely. Just a hatch. So, you can choose not to see as well.'* Concluding, parents want confirmation that their baby is alive and well. Being able to see their baby in whatever shape or form is a way of connecting with their child providing the limitations of the artificial womb. Almost all parents want to see details, and some would like the bag to be translucent or have the option to see the baby or not. However, not one parent would like the bag to be opaque.

Expert

Light can be harmful for the child, especially in the earlier phases. The parent gains however some reassurance from seeing the child. Also the doctor would want to see the child in the early adaptation phases for control. A form where the child is visible to the parents and doctors whilst the womb itself is dark would be ideal.

Shape

Parent

Not one parent liked the form of the artificial womb simply being a bag, but there are varying opinions about what the parents prefer the shape of the artificial womb to be. The main requirement from parents is that the artificial womb is safe and stable, so no one can walk in and take the baby with them. Furthermore, a lot of parents mentioned that they would like the shape of the bag to be round. P5: *'I would like the baby to be in a belly shape, I think. I would like that the best. With a round case for protection but with the possibility of accessing it.'* Especially because the thought that the round shape would help the baby to maintain the fetus position. P11: *'With an oval shape you will wrap the baby up, and that is of course not the idea, the baby should live. So then I think I would go for something round. The baby is not lying in an incubator but instead lying in a fetus position. Therefore, I think about something round.'* Some parents mentioned the option of being able to hold the baby within the bag. P5: *'Some kind pouch or baby carrier. More of a shape of which it is possible to hold it.'*

Expert

The child will take a fetal position because it is efficient. The space between the womb and the child differs in age. At 20 weeks there needs to be more space for the child to develop its joints, however the child starts growing faster than the womb itself does, which “forces” the child in the fetal position due to lack of space. Because the baby lives in this position or moves to this position naturally it will be more at ease if this position remains in the artificial womb.

Material

Parent

When the researchers showed the baby inside the bag, a lot of parents were shocked by the sight. Someone even said, P5: *'I would want to rip the bag open and take my child out.'* Others mentioned that the baby looked lifeless or that it reminded them of meat packed in vacuum. Parents found it very unnatural to see a living human being inside a bag. P1: *'I would think it is so unnatural to have a child in a bag with water.'* Therefore, the parents were asked what kind of material would be a better option. Overall, parents replied that a warmer, softer material would already make it look more natural. P11: *'I was thinking about something soft. Those plastic gloves, doctor gloves, you can inflate them as well. Rubber, silicone. This now feels cold, and that [referring to the gloves] would be softer.'* P4: *'So maybe it is more pleasant when it is flexible and when you can feel it, I think.'* Furthermore, parents liked the box because it reminds them of an incubator, something they already know. However, they would also like the possibility of touching it without the distance of a hard plastic box. P4: *'So maybe it is more pleasant when it is flexible and when you can feel it, I think.'* The best combination would be a removable hardcover to protect the baby and inside a bag of a soft

material which gives parents the possibility of being closer to their child and touching it.

Guidelines

Based on the findings, the following guidelines were composed to design a positive experience from a parental point of view.

The womb should be transparent according to situation

Even though parents are aware that being able to see their baby is unlike the natural womb at that stage, they desire to see their child in order to connect with their baby. This is also important for doctors when monitoring the baby, especially in the early phases of the development of the artificial womb. However, the bright light reaching the baby in the artificial womb will cause the baby stress. Therefore, the womb needs to be dark as much as possible to prevent the baby from getting harmed.

Allow physical contact for reassurance

The parents expressed their desire to soothe their child when their child is in a state of discomfort. Although physical contact is more difficult when a baby is in an artificial womb instead of an incubator, it is questionable whether this soothing element is needed for the baby. Due to the resemblance of the artificial womb and the natural womb, the baby is likely to be in a relaxed state. Therefore, the soothing would only address the desire of the parent.

Provide privacy with opportunity for support

Every parent chose the option for privacy with their child over the presence of support from other perinatal parents in the direct environment of the artificial womb. Accordingly, the artificial womb should be in a private room, but parents should be given options for support from sources and people who can relate to their situation.

Only alarm parents with critical situations

The alarms in the NICU are constantly making sounds. This discomforts and stresses parents as they are continually aware of possible threats. Therefore, signals that show a possible threat should not reach parents. Only nurses receive this constant information and if a threat is present they should act accordingly by providing the parents with appropriate guidance and information.

Extra artificial connection with baby unnecessary

Mothers are aware that they have given birth to their child. They stated that devices that mimic the feeling of pregnancy can often feel fabricated. Therefore, they do not want any form of connection at a distance, including video connection which also feels too distant to be comforting.

Stretching flexible material with removable protective layer

The base material of the artificial womb must be sturdy enough to give the parents the reassurance that their baby is safe, but also soft to the touch. An extra layer of protection would provide more sturdiness, but this layer should be removable so physical contact with the baby in a soft exterior is possible and to refrain from making the child too distant.

The base material that will be touched needs to be somewhat flexible for the baby as well as for the parents. The material should grow or stretch as a normal womb would do to simulate the same safe environment for the baby. For the parent, it is important that the material is flexible so that it can possibly form around the figure of the child, giving the parents a better feel of their child. In addition, the womb should be round-shaped, similarly representing a mother's belly. Resembling this shape will bring forth comfort for the baby, as the baby takes this fetal position normally, and also for the mother. Lastly, if the womb could be safely carried on the belly as if it is a natural womb, this would further resemble a natural environment for the baby and the mother, creating the most ease for both.

Interpretation

In the end, nearly every guideline exhibited the same underlying theme: the parents experience an unpleasant feeling of distance from their child. This feeling is caused by the absence of one of the following two things: reassurance that the artificial womb provides the best care for their child, and the ability to contribute in caring for their child. The absence of both things will cause parental stress. However, if these conditions are addressed, parents will feel more encouraged about their baby being in the artificial womb. For

instance, when parents feel that they can help caring for their child in any way, they will be more at ease than when they cannot (see section Parent-Infant Relations). However, granted that parents cannot provide much help for the baby when it is in the artificial womb, it must focus on providing reassurance for the parent (see figure 2).

DISCUSSION

For this study, 9 interviews were conducted with a total of 11 parents. Although conclusions were drawn from their preferences, these could be different when a larger pool of participants is interviewed. It needs to be taken into account that a group of 11 parents is a relatively small pool of participants when speaking on behalf of parents who have had experience with premature babies. This small group could also mean that a selected outlier in this study is not a significant outlier within a larger target group. Also, the background of the interviewed parents could differ from the background of the average parent.

Furthermore, at the time of the interview, the parents were no longer in the situation of having a premature baby; the interview was done after the fact. It is possible that parents who are experiencing the situation at the time of the interview with all their emotions and stress, different reactions and answers to questions could have been gathered.

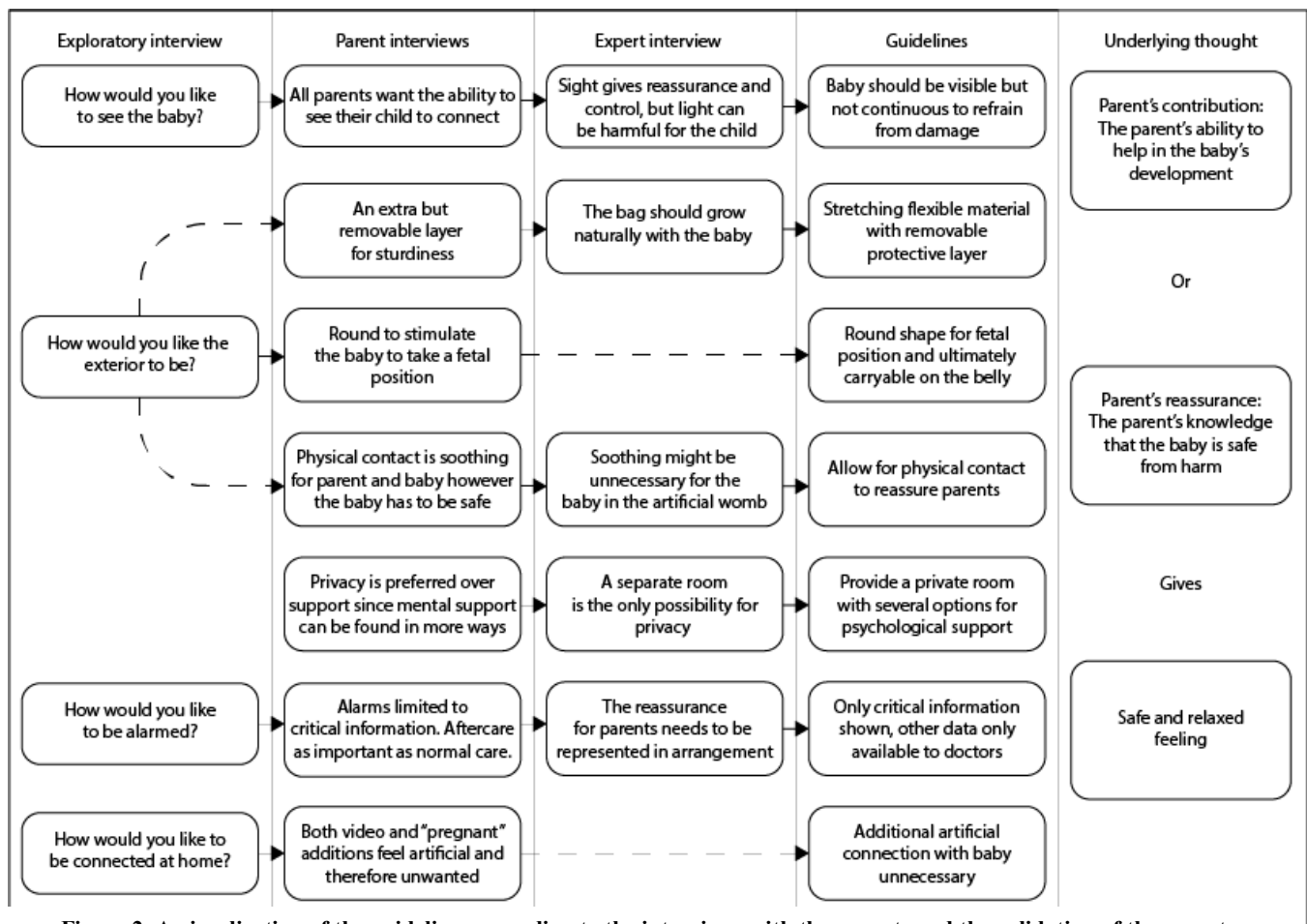


Figure 2. A visualization of the guidelines according to the interviews with the parents and the validation of the expert.

For this study, parents with experience of having a premature baby in the incubator were chosen because future parents with a child in the artificial womb will be in a similar situation. Although the incubator is the closest technology for aiding the development of premature babies, there are still many differences in the experience compared to that of the artificial womb. It would be ideal to interview parents with experience with the artificial womb, but this is not likely for now, for the first human trials on a working artificial womb are most likely years away [12]. Therefore, opinions and preferences of the real time user could be different.

Next, the fathers were in a minority compared to the mothers. Three fathers took part in the interviews and 9 mothers. This could mean that the outcomes in the form of guidelines are more based on the preferences of mothers than fathers.

For the future, it is important to find out which guidelines can realistically be implemented in the development of the artificial womb and how this should be done technically. It could be possible that not every guideline is feasible. Additionally, each guideline can indicate multiple solutions. Although there might be ideas for each guideline, more research should be done on whether the solutions are possible and in fact beneficial for the development of the baby.

CONCLUSION

In the end, the main goal is to understand the preferences of parents to develop design guidelines for the artificial womb and create the most reassuring, comforting experience for the parents. In the interviews, the feeling of distance comes forth from the lack of reassurance of the well-being of their child combined with the inability to help the child. If these elements are addressed and relieved, the stress-level of parents can be reduced. The guidelines therefore are designed towards tackling the twofold cause of parental stress. Since the guidelines are validated on medical terms by an expert, they provide a valuable basis for the future development of the artificial womb.

ACKNOWLEDGEMENTS

The researchers would like to thank our coach, F.L.M. Delbressine, for introducing us to this topic and coaching us this semester and the other coaches of the health squad of Industrial Design for giving feedback during each reflection session. The researchers would also like to thank D.R. Kommers for her input, time and knowledge. Lastly, a special thanks to all the parents who took part in this study and who were willing to be open minded and share their experiences.

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