Virtual Feed: Design and Evaluation of a Virtual Reality Simulation Addressing the Lived Experience of Breastfeeding

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ABSTRACT

Breastfeeding can be challenging, but it is difficult for antenatal education to convey issues associated with the lived experience of breastfeeding. In our work, we explore the potential of interactive simulations to support antenatal education, and present Virtual Feed, a Virtual Reality breastfeeding simulation for parents-to-be developed following a three-step process. (1) We created an experience prototype that features basic VR scenarios and a tangible baby, (2) we engaged in design sessions with 19 parents and parents-to-be to derive design implications to further refine the simulation, and (3) we evaluated the system through case studies to examine the perspectives of parents and parents-to-be on the simulation. Our results show that the simulation successfully engaged users and sparked curiosity, while also encouraging reflection about the challenges of breastfeeding. On this basis, we discuss challenges for the design of simulations with the purpose of supplementing antenatal education.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; *Virtual reality*.

KEYWORDS

breastfeeding, virtual reality, co-design, qualitative research

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1 INTRODUCTION

Breastfeeding brings many benefits for parent and child, but the process is challenging [79]: In the early postnatal stage, many parents feel insufficiently prepared for the reality of breastfeeding, and report that their expectation of breastfeeding does not match reality both in terms of practicalities and the emotional experience of the process [30, 73, 80]. As a result, parents feel overwhelmed [44] and may doubt their ability to breastfeed [20, 44, 79]. This, in turn, negatively affects their intention to breastfeed in accordance with recommendations [11]. In Western societies, antenatal education is designed to address this issue, seeking to prepare parents-to-be for childbirth and breastfeeding [21]. With respect to breastfeeding, many antenatal courses focus on the benefits and high-level practicalities of nursing [57], and typically involve informing parents about health outcomes and teaching them the basics of breastfeeding, for example, how to recognise hunger cues or how to latch a baby [70]. To convince parents to adopt breastfeeding and meet public health goals [58], antenatal education frequently casts breastfeeding as a natural process, idealising breastfeeding as an *instinctive* and *trouble-free* mode of feeding [44, 46, 79]. However, the reality of breastfeeding is often far more challenging [34, 44, 79], with many parents experiencing pain [39], difficulties latching the baby [48], and insecurities about their ability to feed their child [20, 44, 79]. These are intertwined with emotional challenges and practical barriers posed by societal norms and the built environment [73].

As a result of the narrow focus of antenatal education, parents are insufficiently prepared for the reality of breastfeeding [21, 63]. Most importantly, many parents will not have gained any insights into the lived experience of breastfeeding and the associated challenges [62], potentially amplifying the mismatch between expectation and reality once their child is born. Here, information and communication technology (ICT) offers an opportunity to explore novel ways of supplementing antenatal education, for instance, through the creation of simulations or games that touch upon the lived experience of breastfeeding [30]. However, despite this potential, existing ICT systems to support breastfeeding overwhelmingly focus on conveying theoretical knowledge [72], e.g., through websites [1, 28, 38] or mobile apps [22, 77]. As a result, the complexity of the lived experience of breastfeeding is rarely reflected in currently available systems [73].

Our work aims to address this gap through the design and evaluation of an immersive Virtual Reality (VR) breastfeeding simulation that conveys the lived experience of early-stage breastfeeding. Here, VR offers the opportunity of presenting otherwise inaccessible experiences from a first-person perspective [23, 68], making it an ideal platform to complement existing approaches to antenatal education.

In our work, we seek to answer the following two research questions:

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RQ1: What design considerations need to be made when creating interactive simulations to convey the lived experience of breastfeeding and associated challenges?

RQ2: How do parents and parents-to-be perceive an interactive simulation of breastfeeding, and what is its potential for antenatal education?

In line with prior work that designed VR experiences with stakeholders [29, 84], we structured our work into a three-step, qualitative research process. In the first phase, we developed an experience prototype of a VR breastfeeding simulation to be leveraged as an ideation tool. The initial prototype of the simulation combines the Oculus Rift CV1, a tangible representation of a baby attached to an Oculus Touch controller, and a Leap Motion controller to simulate interactions in breastfeeding. In the second phase, we involved 19 breastfeeding parents, partners and parents-to-be in design workshops that address the lived experience of breastfeeding, and perspectives on the VR prototype, and from which we derived implications for design. In the third phase, we examined the perspectives of parents and parents-to-be toward a refined version of the simulation that was created on the basis of the design sessions. This version includes three breastfeeding scenarios in a personal living space, a public park, and an office environment. We engaged in hands-on exploration of the system and semi-structured interviews with ten parents and parents-to-be. While the intended primary application context for the simulation is antenatal education for parents-to-be, we also involved parents with recent breastfeeding experience in our initial evaluation in an effort to mitigate risk for participants, and ensure that the experience provided by the simulation is realistic, but not discouraging. Through thematic analysis [13], we highlight that the experiences provided by the simulation facilitated an intimate emotional experience, and in particular resonated with the lived experience of breastfeeding parents while encouraging nuanced reflection. However, we also observed micro-frictions that potentially hinder immersion in the virtual environment, particularly with respect to the look and feel of the simulation, and frictions associated with unfulfilled expectations of interactivity.

On the basis of these findings, our work makes the following three main contributions: (1) We provide a comprehensive VR breastfeeding simulation that demonstrates the feasibility of ICT to convey the lived experience of breastfeeding, (2) we discuss the relationship between the simulation and reflection - novel experiences that provoke thoughts and challenge the initial understanding of the lived experience [9] - among users, and (3) we critically reflect on the use of technology that conveys lived experiences in the context of antenatal education and early parenthood, highlighting the opportunities and limitations of immersive interactive systems in sensitive settings.

Breastfeeding has many benefits for parents and children, but current approaches that Western societies take toward antenatal education do not sufficiently prepare parents-to-be for the reality of it. Our work is a first step toward unfolding the full potential of ICT in antenatal education in a way that extends beyond conveying factual knowledge by harnessing the power of immersive VR to simulate environments and experiences, thereby giving parents-to-be the opportunity to glimpse at a future which they may find hard to picture and reflect on in the present.

2 BACKGROUND

Here, we give an overview of factors influencing breastfeeding practice within the context of the lived experience of breastfeeding, and we summarise related work on ICT to support breastfeeding.

2.1 General Breastfeeding Determinants

Many factors influence parents' ability to initiate and carry through with breastfeeding. It is important to recognise that some of these factors cannot directly be controlled by parents, e.g., socioeconomic status [2, 50, 56, 67], complications during delivery [42], and medical conditions [67]. Other factors are within the control of parents, and therefore routinely targeted by interventions designed to increase the initiation of breastfeeding or to prolong the duration of exclusive breastfeeding [27, 36, 47, 75]. Factors such as the intention to breastfeed [24, 54, 64] and perceived self-efficacy [11] contribute to the success of breastfeeding. Here, the intention to breastfeed is associated with parents' acknowledgement of the benefits of breastfeeding, positive attitudes toward the feeding practice, social norms, and perceived breastfeeding support [50, 66]. The perception of being supported, having breastfeeding knowledge and skill all help parents maintain self-efficacy throughout the feeding process [11, 50, 66]. Many of these elements, for example, the understanding of breastfeeding benefits, theoretical knowledge about the anatomy of breastfeeding, self-efficacy, attitude toward breastfeeding and professional support structure, are already addressed by antenatal breastfeeding education and existing ICT-based interventions [3, 52, 60, 72].

2.2 The Lived Experience of Breastfeeding

In addition to general breastfeeding determinants, a growing body of work is starting to acknowledge the relevance of the lived experience of breastfeeding and its impact on parents' ability and intention to continue to breastfeed once a feeding relationship has been established [18, 34, 59, 73]. Many new parents find themselves in an initially overwhelming situation of having to care for an infant, and struggle to align their infant feeding practice with the expectation of their family, health care professionals, and wider society on how they should feed their child [73, 79]. Parents' lived breastfeeding experience is often described as complex, messy, and compounded with practical and emotional challenges [73], for example, having to overcome their insecurities, uncertainties about the child's demand, personal norms and physical burdens to be able to breastfeed their baby on demand regardless of the situation (i.e., either in private living spaces or in public areas). Interestingly, the insights gained from antenatal education do not seem to adequately prepare parents for breastfeeding, as they often focus on promoting breastfeeding by presenting the benefits and casting breastfeeding as an instinctive and trouble-free mode of feeding [34, 44, 79]. While this strategy may be effective in increasing parents' willingness to consider breastfeeding at the antenatal stage, this approach glosses over the fact that breastfeeding is a process to be learnt [44, 76], and that it can be painful and demanding, creating a mismatch in expectations about breastfeeding. Consequently, new parents go through an adjustment process when first starting to breastfeed as they are surprised by the reality of the feeding process [34, 65, 79]

and when returning to work as they encounter other practical challenges [73]. The complexity of the lived experience of breastfeeding pushes some parents to proactively look for strategies to cope with arising challenges to regain autonomy and agency [32, 73, 80], e.g., actively seeking reassurance and support that is tailored to their own situation from health care professionals [74] or online sources [31, 32]. However, others are discouraged and discontinue their breastfeeding journey in favour of formula feeding [73]. This transition is often reported as an emotional and confidence-reducing process that parents were not sufficiently prepared for [25].

From the perspective of antenatal education, this is a missed opportunity to better prepare parents-to-be for their feeding journey through more realistic accounts of breastfeeding that can help facilitate the process of expectation setting in the antenatal stage. However, one of the challenges lies within the effective delivery of such accounts, striking a balance between recognition of challenges, discussion of potential problems, while avoiding discouraging breastfeeding. Here, previous work from the Human-Computer Interaction (HCI) research community [30, 73] has highlighted the potential of interactive technology to contribute to this effort, an approach which we discuss in the following section.

2.3 Technology to Support Breastfeeding

A number of efforts have been made to design technology to support breastfeeding at different stages, both within medical and the HCI research community. A recent review of ICT to support breastfeeding identified four types of interventions [72]: self-administered breastfeeding education, systems that encourage breastfeeding, professional support networks, and systems that provide practical support, with educational interventions being the most prominent kind of system. Most of these interventions took a simplistic approach, e.g., by just digitising existing resources into reading materials made available on websites [1, 28, 38] or mobile apps [22, 77].

Within the HCI research community, previous work sought to provide technical systems that address practical challenges of daily breastfeeding practice. For instance, Feedfinder [7] and Moommae [17] are mobile apps that help breastfeeding parents find, share and review places where they felt comfortable breastfeeding in public. Similarly, Milkmatter [78] is a geo-social app co-designed with breastfeeding parents and milk donation centers to facilitate and encourage breast milk donation. In terms of ad-hoc support, Feedpal [82] is a proof-of-concept chatbot designed to explore the opportunities for systems that provide automated first-line breastfeeding support and deliver breastfeeding education. There was also an attempt to facilitate milk-pumping by immersing parents in a soothing VR environment [83], however, neither the system details nor the results of its evaluation has been reported. Generally, prior work supports breastfeeding through the provision of education or pragmatic support, but do not yet address the lived experience of breastfeeding, an insight difficult to comprehend without first-hand experiences [21].

More recently, the HCI research community has begun to recognize the relevance of lived experience in the context of breastfeeding and early parenthood. Gui et al. [32] examined peer support seeking among mothers-to-be in online communities in the prenatal stage. The work suggests the need for prenatal technology that communicates experiential knowledge according to the maternity stage of mothers-to-be, and shifts the focus from fetus-centred design to the design for woman-centred maternity care. Tang et al. [73] investigated the role of technology for breastfeeding, detailing the complexity of parents' lived experience of breastfeeding and highlighting the relevance of the lived experience for technology that supports breastfeeding in both prenatal and postnatal stages. Focusing on the postnatal stage, Gibson and Hanson [31] leveraged ethnography to understand ICT use among new mothers. The work shows that new mothers make use of technology to build confidence through support seeking from peers, and to reclaim their new identity as a mother, highlighting the potential of ICT in empowering new parents to become more resilient to challenges in the early postnatal stage. Generally, findings from these pieces of research highlight the relevance of the lived experience of parenthood, and suggest that early parenthood can be a period of vulnerability.

Building on this growing understanding of the importance of the lived experience, our work explores how it can be captured and integrated in antenatal education to better prepare parents-to-be for early parenthood. In the context of breastfeeding, previous work [30, 72] has highlighted the potential of immersive interactive systems such as games or XR systems as a means of communicating the lived experience to parents-to-be. Here, the latest generation of VR systems in particular offers an opportunity to fully immerse users in experiences that are otherwise hard to access at a high level of fidelity, and it has previously been used to simulate sensitive situations, for example, witnessing acts of racial discrimination [19], confrontational customer behaviour [23], or prompting reflection on death and isolation [6]. In our work, we leverage this potential to provide parents-to-be with a first-person experience of early-stage breastfeeding in different settings, directly transposing users into different scenarios that reflect challenges associated with the lived experience of breastfeeding. Thereby, our work seeks to complement the existing approaches toward delivering breastfeeding education at the antenatal stage.

In the remainder of this paper, we discuss our three-stage research process that we established to craft our VR simulation: (1) development of a VR experience prototype, (2) designing VR breastfeeding experiences with parents and parents-to-be, and (3) exploring the perspective of parents and parents-to-be on the VR breastfeeding simulation.

3 PHASE I: DEVELOPMENT OF A VR EXPERIENCE PROTOTYPE

The first phase of our work contributes a VR experience prototype [81] that helped us explore the basic suitability of VR to simulate breastfeeding experiences. This phase served two purposes. First, we wanted to explore the technical feasibility of creating a VR simulation that leverages a tangible doll that can be held by users as the input device, achieving an experience that mirrors real-world breastfeeding. Second, we wanted to create a prototype to facilitate the ideation process with participants in the second phase of our work, offering them a starting point for reflection on what a VR breastfeeding simulation could look like, and providing a foundation to respond to RQ1 in Phase II (see section 4). Here, we give an

overview of our design approach, detail our prototype development process, and present the resulting system.

3.1 Technology as an Experience Prototype

Prototypes are important means to communicate and explore design ideas. The design of interactive systems that leverage software and hardware that stakeholders are not familiar with is challenging, as stakeholders may have difficulty speculating about the final look and feel of the system [14]. This risks using up resources and unnecessarily burdening participants, which is particularly relevant when working with new parents. There is a body of research that examines *Experience Prototyping* [14, 35, 49] as an approach to present the roles, the functions, and the look and feel of an artefact to elicit ideas, so that the artefact can be reshaped and has its meaning reinforced. Reflecting on our work, there are two aspects that afford the creation of an interactive rather than static prototype: (1) the relative novelty of VR, and user groups who might as a result struggle to imagine what respective systems could look like, and (2) the potential sensitivity of the setting, which requires careful communication of the intended experience. This implies the need to craft an experience prototype that reflects the potential and the limitations of VR. The challenge, however, lays in crafting a prototype at a fidelity level that encourages the generation of design ideas, while maintaining realistic expectations of current VR among participants.

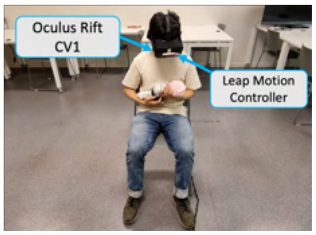
3.2 Prototype Design and Development

Here, we describe our prototyping process. Our design decisions were informed by breastfeeding literature summarised in section 2.1 and 2.2 to craft two VR experiences which hint at the influences of norms and the environment on the feeding experience. In this phase, we decided not to include other aspects of breastfeeding in an effort to strike a balance between a prototype that encourages ideation and that showcases the capability of VR.

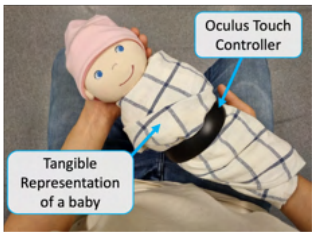
Our prototype comprises three main parts: an Oculus Rift CV1 headset and its tracking sensors, a plush doll or pillow representing a newborn with an Oculus Touch Controller attached, and a Leap Motion controller attached to the front of the VR headset (see figure 1). Here, we track the tangible representation of the baby indirectly via the attached Oculus Touch Controller, and the users' hands via the Leap Motion controller. Our choice for the Oculus Rift CV1 was motivated by its low hardware requirements, low cost, and native Leap Motion support which enables simultaneous hands and VR controllers tracking. The VR experiences were developed using Unity and software development kits (SDK) from Oculus and Leap Motion.

During our design process, we prioritised the following three aspects: (1) user interaction, (2) system aesthetic, and (3) basic breastfeeding scenario development. The result is a functional prototype of a VR breastfeeding simulation that combines a tangible representation of a baby with two basic breastfeeding scenarios, and that allows users to imitate the act of feeding a baby in these settings by bringing the tangible close to their chest.

3.2.1 User Interaction. Here, we aim to create user interactions that approximate interactions between parents and a newborn baby, and stimulate closeness to the virtual baby. Within the VR experiences,



(a) Simulation setup (third person view)



(b) Simulation setup (first person view)

(c) VR view from the user perspective

Figure 1: Simulation set up, tangible and digital representation of the baby and the VR view from the user perspective

the user can see an avatar of themselves in a sitting pose from the first-person view (see figure 1c, 2 3). We take advantage of the motion tracking capability of the Oculus Rift's IR-constellations tracking sensors and the hand tracking sensor to mirror the user's body movements to the virtual space. The pose of upper body parts, such as elbows, shoulders and neck, which are not tracked by the hardware, are estimated using Forward And Backward Reaching Inverse Kinematics (FABRIK) [5]. Together with support for the tracking of the tangible probe representing the baby, we crafted two main interactions:

Figure 2: Free hand interaction

Free hand interaction enables delicate interactions with the virtual baby such as touching and caressing. Concretely, the user can, for instance, gently stroke the nose of the baby with their fingers (see figure 2) or caress the baby's head.

Holding interaction invites the user to hold the tangible close to their chest, i.e., mimicking the act of feeding a newborn (see figure 3). For this early prototype, we intentionally did not integrate the latching and feeding mechanic, as this experience prototype was meant to demonstrate the potential of VR and encourage design ideas.

Figure 3: Holding interaction

3.2.2 System Aesthetics. When designing the aesthetics of our system, creating a realistic environment posed our main challenge. Within the virtual environments, presenting humanoid characters is challenging due to perceived eeriness when confronted with almost human-like objects as explained by the uncanny valley [55]. A common strategy to address this issue is to avoid photo-realistic graphics and consider the user diversity in representations [69]. Therefore, we applied a simple, non-realistic low polygon style when designing the VR experience (see figure 1c, 5 and 6). This style supports our design goal of leaving room for participants' imagination during the design process and helps reduce the risk of approaching the uncanny valley. To this end, we also provide a possibility to adjust the skin tone of the user avatar and the virtual baby to match the skin tone of the user.

Figure 4: (From left to right) Physical representations of the baby, VR head mounted device and sensors for hands and motion tracking

In terms of the tangible device to represent a baby, we opted for a small cylindrical pillow and plush dolls from Haba [33], which map well onto young babies in terms of size, and can be purchased in a range of skin tones. These tangible probes offer different levels of abstract presentations of a newborn (see figure 4). Each tangible probe is attached to an Oculus Touch Controller so that it can be tracked in VR. We inserted extra weight and swaddled the dolls to approximate the characteristics of a newborn baby. The final form of the input device weighs 1.2 kg.

3.2.3 Breastfeeding Settings. We designed two basic breastfeeding settings, each hinting on different levels of social and environmental influence on the lived breastfeeding experience (see section 2.2 and [4]). These settings are intended to prompt participants to reflect on breastfeeding in different environments.

Personal Living Space (figure 5) was crafted to portray a common breastfeeding setting with minimal interference from the environment in the early postnatal stage. We immerse the user in a living room that has furniture, appliances and baby-related objects. Background noises from appliances and nearby streets were added to improve immersion.

Figure 5: Scenario 1 - Personal living space

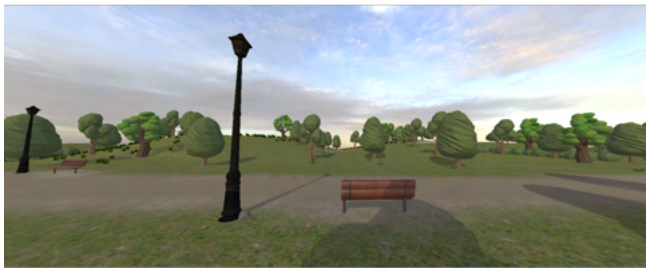


Figure 6: Scenario 2 - Public park

Public Park (figure 6) aims to convey an outdoor breastfeeding experience with the presence of strangers, highlighting the influences of environmental and social norms on the feeding experience [73]. Here, breastfeeding is depicted as an activity in a shared public space.

4 PHASE II: DESIGNING BREASTFEEDING EXPERIENCES WITH PARENTS AND PARENTS-TO-BE

In the second phase, we involved parents and parents-to-be who planned to breastfeed in workshops to design visual components of the simulation, and to craft scenarios that reflect plausible experiences and challenges of the feeding process. We reflected on the elicitation techniques used in prior HCI research in the parenthood space (e.g., [7, 78]) and opted for design workshops as an approach to involve parents because they enable in-depth discussions about the lived and anticipated experience of breastfeeding, and would allow us to explore multiple design ideas [78]. Through this phase of our work, we sought to answer the first research question (**RQ1**), *What design considerations need to be made when creating interactive simulations to convey the lived experience of breastfeeding and associated challenges?*

4.1 Method

We followed an exploratory approach to inquire concrete design considerations, breastfeeding scenarios and associated challenges to be simulated in VR through design workshops consisting of four activities:

Activity 1: A drawing task with the purpose of supporting visual elicitation [61], in which we asked participants to sketch and comment on a picture of themselves in a breastfeeding setting that they experienced or anticipated. We opted for this approach for two reasons: first, we leveraged it as an icebreaker to allow participants to become more comfortable in the research setting, and second, visual elicitation offers the opportunity of engaging research participants in discussion of emotional topics, with the visual representation serving as a starting point for reflection and further exploration [8]. The goal of this task was to gain insight into the lived and anticipated experience of parents and parents-to-be, and how they view the presentation of themselves in breastfeeding settings.

Activity 2: A semi-structured interview guided by eight sketches of common breastfeeding settings (figure 7) that drew from previous work (see [73] and section 2.1) in this space. Here, the participants were given an opportunity to pick sketches that they would like to discuss, and to comment on breastfeeding settings that were not presented. This approach helped participants reflect on the challenges associated with breastfeeding and the influence of social and environmental factors on the feeding experience. The goal of this task was to identify scenarios for inclusion in the final simulation on the basis of common breastfeeding experiences among participants.

Activity 3: A moodboarding task was carried out in two steps: we first demonstrated the experience prototype developed in Phase I. We presented a video instead of letting the participants experience the simulation in response to the pandemic. We then invited the participants to express visual design suggestions for the VR experiences by means of creating a mood board using a shared PowerPoint file. Through this task, we aimed to explore participants' preferences on the aesthetics with respect to the virtual breastfeeding environments, and the physical and digital representation of the baby. We chose this approach because mood boards allow participants to better express their thoughts through concrete visual examples, and to help avoid ambiguities when communicating visual information verbally.

Activity 4: A final storyboarding activity, in which we invited participants to sketch and describe two breastfeeding scenarios: a pleasant one that they enjoy looking back (or forward) to, and a setting in which they did or would find it challenging to breastfeed. In this activity, we asked participants to describe the setting and their relationship with the baby, and invited reflection on barriers and facilitators of breastfeeding. The goal of this activity was to draw together previous insights, and to further consolidate participant preferences for the design of the simulation.

4.2 Participants and Procedure

Nineteen participants (thirteen female, six male; thirteen in 26-35 and six in 36-45 age groups) were recruited through a snowball sampling method with advertisements posted on social media, and through word-of-mouth between February 15, 2020 and April 16, 2020. Participants were breastfeeding mothers (11), partners (5), parents-to-be who planned to breastfeed (3), and they had one child (11), two children (2) and three children (3). The youngest child was 15 months old (SD=9.45), and the breastfeeding duration of the youngest child was up to 1 month (1), up to 3 months (2), up to 6 months (2), up to 9 months (1) and up to one year or longer (10). Participants resided in Western Europe, but grew up in Western Europe (6), Eastern Europe (5), Southern Europe (4), South Asia (1), Southeast Asia (1), East Asia (1), South America (1).

We had planned to carry out in-person design workshops, which we later adapted to take place online via video call using Skype for Business [53] or Zoom [85] in response to the Covid-19 pandemic. Instead of working with bigger groups, we opted for inviting participants in pairs where possible, allowing us to better manage the process of working with a range of digital tools such as video-conference and audio recording software, shared PowerPoint files that served as a guide and an editable canvas, and smartphones that facilitates the exchanges of photographed drawings. The workshops lasted about one hour, taking place during the hours that best suited participants' parenting routine. Participants were paired with their partner (12), with another participant (4), or took part individually (3). Participants gave informed consent through an online form, and were asked to give consent verbally at the beginning of the design session. Each design session was conducted in English, and comprised the four tasks described in section 4.1. Each task lasted about 12 to 18 minutes. At the end of each session, participants were given opportunities to ask questions.

All sessions were audio-recorded and later transcribed; artefacts created during the sessions were photographed (by the participants) and/or saved for later analysis. Participants received a payment of 20 Euros or a gift card of the same value. The research protocol (including the switch to digital sessions) was approved by the institutional ethics board.

4.3 Data Analysis and Interpretation

We structured our data analysis process into two stages: investigation of the lived or anticipated breastfeeding experience and exploration of the aesthetic of the simulation.

In the first stage, we analysed data obtained during tasks 1, 2, and 4 (see section 4.1) following reflexive thematic analysis outlined by Braun and Clarke [13]. The analysis was led by the first author, and transcripts were read and re-read by the first author, coded and organised into themes. Where relevant, participant sketches were leveraged to complement analysis, and to make sense of participant statements. Here, we framed our analysis in line with the approach of Braun and Clarke [12], whom appreciate subjectivity and in-depth engagement with the data throughout the analysis process. The themes were then reviewed within the research team. We identified 259 data points assigned to initial 41 codes. The codes were further refined to 17 codes, from which two main themes were crafted (see section 4.4).

In the second stage, we analysed participants' mood boards from activity 3 by organising individual choices into larger groups (see figure 10) based on artistic style, colour scheme, and the context of the image (e.g., indoor furniture, outdoor scene). This approach is in line with other HCI research, e.g., [37, 45], and it helped identify and refine visual styles to apply when designing the virtual baby and VR breastfeeding settings. In addition, we drew inspiration for the design of breastfeeding scenarios from participants' sketches of environments in which they commonly breastfeed.

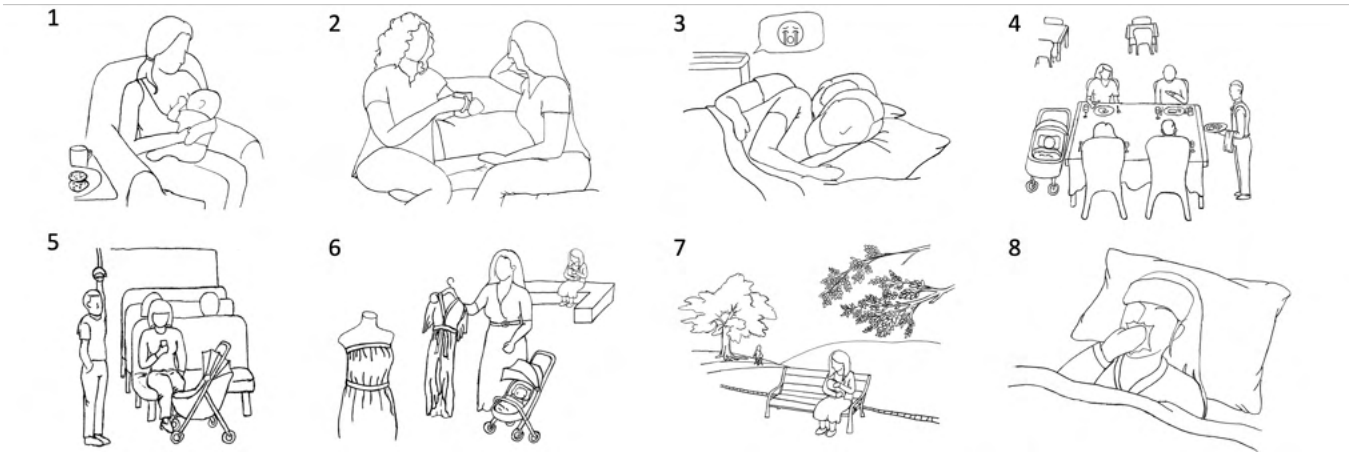


Figure 7: Sketches of breastfeeding related scenarios that guide the target group or interview in Activity 2

Because of the reflexive nature of the analytical approach and the sensitive setting of our work, understanding how researchers' individual backgrounds may have affected the interpretation of findings is important. The main researcher is male and has a background in computer science, and has worked extensively on technology and parenthood, but is not a parent themselves. The other two authors are researchers trained in electrical engineering, computer science and media studies. The female member of the research team has personal breastfeeding experience (which was neither overly positive nor negative), while the other was a partner of a breastfeeding parent. The team was supported by a breastfeeding expert, who is actively involved in antenatal education and lactation consultation. Generally, the research team believes that all ways of nourishing a baby should be considered breastfeeding, whether milk is expressed or fed from the breast.

4.4 Results

Here, we present the two main themes crafted during the first stage of the analysis, *Embracing the Asymmetry Inherent in Breastfeeding While Sharing the Burden (and Joy)*, and *Breastfeeding is a Process of Learning and Adaptation*. We then present concrete visual design implications derived from the stage two analysis.

4.4.1 Embracing the Asymmetry Inherent in Breastfeeding While Sharing the Burden (and Joy). This theme describes how breastfeeding parents draw strength from the support of partners and family members, and can also be affected by the lack thereof. It highlights how embracing the asymmetric nature of breastfeeding (i.e., typically, only one parent directly breastfeeding the child, while the other is involved in other ways) contributes to a successful feeding journey.

Here, participants who breastfed highlighted how they were supported practically or emotionally by their partners and expressed their appreciation for this support, particularly when encountering challenges associated with breastfeeding. For example, one participant commented "*I had some issue related to breastfeeding, it wasn't an mastitis but it was like a block milk. [...] because you feel so weak [...] somebody has to cook for you, make you something to eat even bring you a cup of water*" (P19 breastfeeding parent). Other participants stressed the importance of emotional support from her partner "*it was much more difficult in the beginning [...] what's really important is, partner encourages. Because if you have a doubt, the partner is encouraging and then it's much easier.*" (P15 breastfeeding parent). Shared efforts of breastfeeding were further manifested through seemingly subtle acts and gestures that communicated to the breastfeeding parent that they were not on their own, e.g., "*bringing my (the mother's) phone or putting a nice program on the television or something to drink for the (breastfeeding) duration or taking over the baby in the end*" (P1 breastfeeding parent). Likewise, absence of this support evoked negative emotions in the breastfeeding parent, e.g., "*[It feels] lonely sometimes to be the only one awake with the baby where partner is sleeping*" (P1). Beyond direct support, there was broad agreement among breastfeeding parents that the plain presence of the partner is pleasant while they breastfeed (P12, P8 breastfeeding parent, P19, P5, P15, P3 parent-to-be), suggesting that it is an experience that they enjoy sharing, and that can become more burdensome in solitude. This is also reflected in the participants' sketches of themselves (see Figure 8), where many include the partner in a situation within their home.

While the breastfeeding parents widely embraced the asymmetry of breastfeeding and appreciated their partners' involvement as described above, perceptions of partners varied. Most strikingly, we observed a sense of helplessness in partners. For example, one partner suggested that they felt "*a bit useless, [...] want to help but you just cannot help, because you can't latch yourself*" (P16). In terms of providing support, there was a strong focus of partners on introducing the baby to bottle feeding (with breast milk or formula) to be able to take over entire feeds. While this is valuable that partners can take over feeds at night or while the breastfeeding partner is away, partners' fixation on helping with infant feeding suggests they may be (dis)missing the importance of indirect support, trying

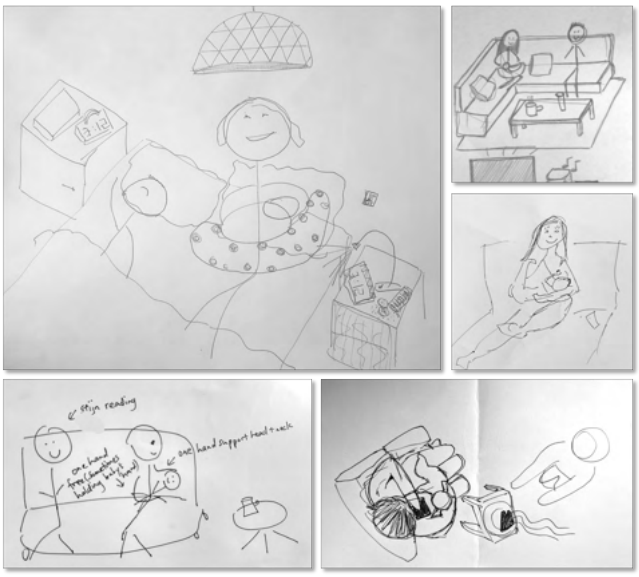


Figure 8: Participants' drawings illustrating their experience of breastfeeding in private spaces

to turn the process into a *symmetric* one, rather than embracing the asymmetry of the feeding process with a unique role for each parent.

4.4.2 Theme 2: Breastfeeding is a Process of Learning and Adaptation. This theme centres around parents' experiences of settling into breastfeeding, and their strategies to overcome challenges throughout their breastfeeding journey. This includes adjusting their expectations of the needs of their baby, and adapting to the expectations of other people.

In terms of learning how to breastfeed in the early stages, there were many instances of parents describing issues related to the process of latching the baby (P6, P2 breastfeeding parent, P4 breastfeeding parent, P5), and dealing with mastitis (P6, P4) and blocked milk ducts (P19). Participants also suggested that there is an element of doubt and uncertainty when first starting to breastfeed that requires parents to be emotionally resilient. For example, participants highlighted that "*you don't know how to latch, how to do it, am I doing it right? My baby is hungry because I'm not doing it right, basically the same thing, it discourages you, but once you realise that when you keep trying, and you manage it*" (P15).

Additionally, parents pointed out that they had to adapt their expectations with respect to breastfeeding and the needs of their baby. For example, one participant expressed their constant feeling of being "*nervous, [...] because I worry about the baby, [...] because you might have to be available in any second*" (P19). We also observed instances where parents were surprised that breastfeeding could be painful, e.g., "*one thing that's blind sighted me as mom, nobody told me that it's gonna hurt*" (P2).

Likewise, our data suggest that parents needed to adapt to breastfeeding in the presence of others, and/or outside of their own home, falling into stride with their baby's needs and exploring their own comfort zones. Here, our findings broadly underscore previous work [7, 73] with an overwhelming majority of parents highlighting having to develop strategies to cope with a lack of suitable amenities where parents can breastfeed, i.e., places that offer privacy and are quiet so that the baby can feed; also see Figure 9 which shows that the majority of challenging scenarios provided by participants includes public and/or noisy areas. While there was consensus that "*if you have to do it (breastfeed), then you do it*" (P12), many participants reported having to breastfeed in uncomfortable and confined spaces to maintain privacy, for example, "*in the bathroom*" (P12), "*go to the car or [...] in the corner table with my back towards somebody*" (P5).

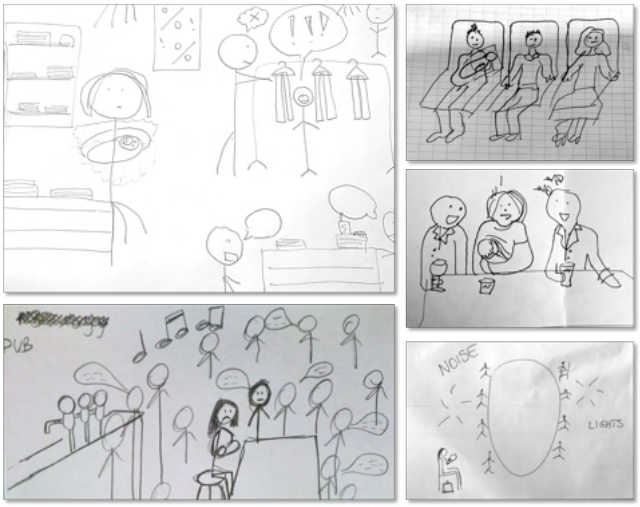


Figure 9: Examples sketches made by the participants, showing their lived or anticipated breastfeeding experiences in public space

Reflecting on the challenge of feeding the baby outside their own home, participants argued that prior exposure to breastfeeding scenes (e.g., seeing siblings being breastfed when growing up) helped normalise public breastfeeding at a personal level (P2), but also stressed that there is also a need for attitude change toward breastfeeding at the societal level: *"I just don't understand it like if the child is hungry, of course you have to feed it why would you, you know, hmm, let them cry. [...] it's a bit of attitude that needs to change."* (P8).

4.4.3 Directions for Design Derived From Visual Artefacts. Here, we present findings from stage 2 analysis where we drew implications for the visual design of the baby and breastfeeding scenarios from our visual data (figure 8, 9, and 10).

In terms of the visual representation of the baby, we observed disparities in the preferences of style and body proportion, ranging from hyper-realistic looks to 3D cartoon styles (see figure 10), suggesting that it will be difficult to create a visual style that will address all preferences. In terms of breastfeeding settings, there are two types of environments that stood out in our data: private living spaces, and indoor and outdoor public spaces with the presence of others (e.g., parks, restaurants and meeting rooms). When further exploring the design preferences for those scenarios, we

Figure 10: Groups of images collected from participants' mood boards

observed a strong preference for a pristine look and high-fidelity 3D modelling style that contrasts the simple, low-polygon visual style that we adopted in Phase I. Participants also expressed their fondness of elegant-looking indoor spaces, and a preference for gender-neutral colours such as yellow and green. This colour choice is also mirrored in selections of baby clothing, where the majority of participants opted for pastel colours, with yellow and grey being preferred colours. Generally, these choices reflect an aesthetic that is frequently associated with the early experience of parenthood in the context of consumer culture (i.e., an emphasis on the safe, clean, and *cute*, see [15] p. 147).

4.5 Revised Prototype

Findings from the design workshops highlight the complexity of the lived breastfeeding experience which, in many cases, is unanticipated by parents: they report having to bare with a range of challenges, most notably, the insecurity about their own ability to satisfy their baby in addition to the physical burden. This suggests the need to **design experiences that spark concrete reflection on breastfeeding challenges** with respect to the uncertainties involved in breastfeeding along with on-demand feeding. More generally, our data **expose the strong influence of societal norm and the built environment on breastfeeding experiences**, especially when feeding in public spaces. This suggests that the conveyance of the lived experience needs to address the impact of norm and environment by introducing parents-to-be to the experience of nursing in different settings. Finally, findings also underscore the importance of nuanced support from partners and the asymmetrical nature of breastfeeding. This offers an opportunity to simulate scenarios that **include and highlight their contribution**, which can be nuanced and does not necessary involve feeding the child because each parent has a unique role in the breastfeeding journey. We also encountered a number of aspects that are difficult to integrate in our simulation (e.g., physical burden and pain), and we discuss this further in section 6.2.1.

Taking these aspects into account, we iterated on our VR breastfeeding simulation, discussing user preferences in the research team and reconciling them with technical constraints. This resulted in a redesigned 3D model of the baby (incorporating the full feeding mechanic, i.e., an animated baby that responds to user inputs and latches to the user's breast), a redesign of the two existing breastfeeding scenarios, and the addition of one further scenario. To ensure an acceptable experience for participants at the evaluation stage, the simulation was reviewed throughout development (e.g., realism of the feeding mechanic and challenges the user encounters) by a lactation consultant who took up an advisory role. Thereby, we sought to ensure that the system was generally appropriate, and sufficiently accurate in terms of breastfeeding elements that we simulate.

4.5.1 Presentation of the Simulated Baby and Integration of Feeding Mechanic. In terms of visual presentation of the virtual baby, we followed the *directions for visual design* (section 4.4.3), and crafted a morphing humanoid 3D model that we animated to reflect the behaviour of a young baby during breastfeeding (see figure 11). We also included audio cues (e.g., crying, or small sounds) that match

Figure 11: Non-verbal cues representing states of the virtual baby throughout the latching and feeding process

the facial expression of the virtual baby. Additionally, we adjusted the clothing of the baby to be gender-neutral, reflecting participant preferences.

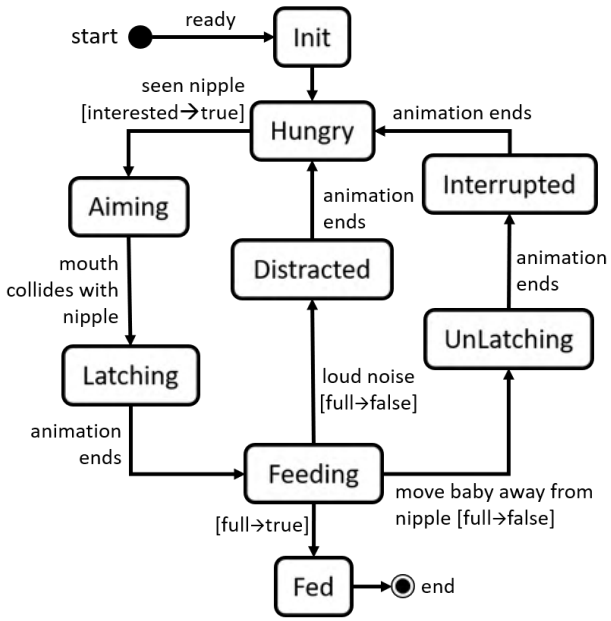


Figure 12: State-machine-diagram modelling the behaviours of the virtual baby

The behaviour of the baby and the feeding mechanic were modelled to convey the uncertainty aspect of breastfeeding, in which a young baby communicates with their parent and reacts to parental interaction through audio and non-verbal cues. The feeding mechanic and the behaviours of the baby are presented in a state-machine-diagram, which comprises nine states (see figure 12). Each state can be triggered by a user input event (e.g., turning the baby so that its mouth faces the breast), random events (e.g., the unpredictability of a baby's interest in being fed), a time-out event of the previous state (e.g., not latching or satisfying the baby's demand within a time frame), or pre-programmed events in the virtual space (e.g., sudden noises that would distract the baby). In terms of the latching process, we leverage the collision detection feature of Unity and Leap Motion's Interaction Engine SDK to approximate the interaction of pulling the shirt down to expose the left breast and to detect the proximity of the virtual baby's mouth to the breast, so that the user can try aiming the baby mouth to the virtual breast, initiating the latching process.

4.5.2 Simulated Breastfeeding Scenarios. Drawing from our qualitative findings, we crafted three breastfeeding scenarios (see figure 13), all aimed to *spark concrete reflection on breastfeeding challenges* and address *the influence of societal norm and environment on breastfeeding experiences*:

Scenario 1: Personal Living Space. This scenario conveys the experience of breastfeeding in one's home in the early postnatal period. Here, *partner support is portrayed subtly* through a situation in which the doorbell rings while the user is still breastfeeding (and hence not mobile), and a pre-programmed humanoid agent answers the door on their behalf.

Scenario 2: Public Park. This scenario invites users to feed their baby in a wide-open public green space, where other people carry out leisure activities (e.g., jogging, hanging out with friends), and are clearly visible to the user while also making noise. Additionally, there are sudden distractors like an airplane flying by that can startle the baby. This scenario gently introduces breastfeeding in public, only confronting the user with other persons at a distance.

Scenario 3: Work Environment. This scenario presents a feeding experience in a much more confined space (an unoccupied meeting room) which parents might encounter when first returning to work. It is designed in a socially more challenging way: the room is constantly passed by colleagues on the outside, whose

talking can be heard within the room. Additionally, users are interrupted by a colleague who accidentally opens the door, and there is pressure to finish the feeding session within a certain time frame.

Figure 13: Panoramic renders of the redesigned breastfeeding settings in the personal living space, public park, and a meeting room

At the end of each scenario, we present a short message highlighting aspects not included in the simulation, e.g., pain, or different feeding position. Thereby, we want to make explicit what the shortcomings of the current system are.

5 PHASE III: EXPLORING USER PERSPECTIVES ON THE VR BREASTFEEDING SIMULATION

To evaluate our simulation, we involved breastfeeding parents, partners, and parents-to-be in an exploratory study that examines their perspective toward the simulated breastfeeding experiences in VR. Concretely, we invited them to share their impression of the simulation, thoughts on the experience of breastfeeding a baby in VR in relation to their lived or anticipated breastfeeding experience, appropriateness, and potential in supporting antenatal education. Here, we primarily aim to address (**RQ2**), *How do parents and parents-to-be perceive an interactive simulation of breastfeeding, and what is its potential for antenatal education?*, while further supplementing RQ1 and the findings from the previous phase.

5.1 Method

We invited participants to experience our VR breastfeeding simulation that we developed in Phase II (section 4.5) in an in-person evaluation session, and we leveraged semi-structured interviews to support open-ended exploration of participant perspectives on the simulation. In our interviews, we addressed three main areas: 1) impression of the virtual baby and the simulated scenarios, 2) relationship between simulation and the lived or anticipated breastfeeding experience, and 3) appropriateness of the simulation and perceived opportunity to integrate it into antenatal education. We asked questions like "*What is your first impression of the simulation?*", "*How was the experience of feeding the virtual baby?*", "*What do you think about the scenarios presented in the simulation?*", and "*How would you imagine integrating the simulation in antenatal education?*". The full list of interview questions is provided in the supplementary materials.

5.2 Participants and Procedure

We recruited ten participants (nine female, one male; 8 in 26-35 and two in 36-45 age groups) through a snowball sampling method with advertisements distributed at a local family care centre, on social media, and through word-of-mouth between August 1, 2021, and August 31, 2021. Participants were breastfeeding parents (6), parents-to-be (3), and partners (1). Among parents, participants have one child (5), two children (2), three children (1) and their youngest child ages on average 19.79 months (SD=20). All participants resided in Western Europe, but grew up in Western Europe (5), Eastern Europe (3), Southern Europe (1), and North America (1). There was no overlap between participants in the design sessions and those involved in this evaluation. Participants took part individually in the user study that lasted about one hour. Participants gave informed consent through an online form before the study took place, and were asked to give consent verbally at the start of the study session. Each session was conducted in English and comprised of two parts: experiencing the VR breastfeeding simulation developed in phase II followed by a semi-structured interview. The simulation experience lasted about 22 minutes (SD=4.90) and the interview lasted 29 minutes (SD=6.54). At the end of each study session, participants were given an opportunity to ask questions and were compensated with a cash payment of 20 Euros. All study sessions were audio-recorded and then transcribed for analysis. The research protocol was approved by the institutional ethics board, and in line with the local Covid-19 regulations. Here, precautions were taken to mitigate the risk of transmission, including disinfection of study materials as possible (e.g., VR headset), and only running one evaluation session per day as to not invite multiple participants into the same space in close succession.

5.3 Data Analysis

Interview transcripts were analyzed following reflexive thematic analysis of Braun and Clarke [13]. Analysis was led by the first author who read the transcript repeatedly to achieve familiarisation, followed by multiple rounds of coding. Candidate themes were reviewed and discussed within the research team, and refined by the first author. In total, 493 data points were assigned to 82 codes, which were further refined to 16 codes, and finally, two themes were crafted. For information on author positionality, please see the final paragraph in section 4.3.

5.4 Results

Here, we present themes crafted from the interview findings, which focus on the simulation and its potential to create *Emotional Resonance With the Lived Experience of Breastfeeding Parents*, and *Micro-Frictions that Hinder the Conveyance of Breastfeeding Experiences* that primarily addresses points at which the experience needs to be expanded.

5.4.1 Emotional Resonance With the Lived Experience of Breastfeeding Parents. This theme describes how the simulated experience emotionally involved users, and triggered reflection on the complexity of the lived experience of breastfeeding. Generally, participants were very enthusiastic about the simulation, suggesting that it was "*playful*" (P5 parent-to-be) and sparked their curiosity to explore further, "*very nice*" (P4 breastfeeding parent, P6 breastfeeding parent), "*impressive*" (P8 breastfeeding parent), and "*immersive*" (P9 partner of a breastfeeding parent). Participants with previous breastfeeding experience suggested that the behaviour of the baby and simulated scenarios mirrored their lived experience in the early postnatal period, **perceiving the simulation as realistic, triggering flashbacks to memories of early parenthood**: "*it (the simulated experience) was close, as close as it can be to the real breastfeeding [...] it's also very realistic for a virtual reality game. Indeed, the baby when he cries, he cannot latch and he gets very upset when he's very young*" (P4 breastfeeding parent). Likewise, the simulation prompted reflection on these memories, with a partner commenting that "*the new thing that the simulation gave to me, is that I never realised, that's when my partner was breastfeeding that, I could play such an important role, hmm, by trying to eliminate distraction. Hmm, and I just realised that now and so if I would have known that, before then maybe I could have helped, even more by just, knowing explicitly that role.*" (P9 partner), highlighting the degree to which the simulation facilitated reflection, and could potentially contribute to antenatal education.

Our data further suggest that **the simulation revealed the complexity of the lived experience of breastfeeding in a nuanced way**, facilitating intimate and joyful moments with the virtual baby, while also teasing out challenges.

Most interestingly, we observed delicate moments of bonding in which users appeared to be completely immersed in the simulation. For instance, one participant commented that they "*immediately started talking to the baby, you know, talking softly to it [...] I really felt that that kind of connection to the baby and started treating it like how I would kind of talk to my son when he was a baby.*" (P9 partner), and participants reported engaging in additional actions to keep the baby happy, e.g., "*then it started crying, I was already rubbing its belly a little bit.*" (P8, breastfeeding parent). Beyond these bonding moments, participants reported experiencing a series of emotions throughout the act of (virtually) nursing the baby, e.g., they expressed feeling "*happy when I see the baby is latching. sometimes I felt anxious when the baby is not latching, and they are trying to find a good position, so I also felt a bit anxious when the baby was first moving around and I have to go back and forth, just not to lose the baby temper.*" (P4 breastfeeding parent), but also "*annoyed when it started crying, <laugh> that I failed*" (P5 parent-to-be), reflecting issues associated with the early breastfeeding experience.

Our data also suggest that **challenging aspects of breastfeeding included in our simulation contributed to a realistic and relatable experience**. For example, participants appreciated the latching process, commenting that "*in the real life, you also have uncertainties <laugh>, of course, in this sense it is realistic enough, to show the impression that it's not that easy to breastfeed*" (P2 breastfeeding parent). Here, parents-to-be pointed out that the simulation helped them reconsider their expectations of breastfeeding, stating that "*it was more difficult than I thought it would be. I know, they warn you that breastfeeding is not always easy. But I always think like yeah, yeah, but, It looks so easy so it will be easy. I think it was good that it wasn't very easy in the VR*" (P5 parent-to-be) and "*I was actually surprised how long you really have to hold it until it falls asleep*" (P10 parent-to-be). Furthermore, several participants highlighted how relatable the experience is in the home scenario, "*it's nice that you can see that there's another person in the (virtual) room that can open the door because I was wondering what should I do now. Because those are the situation that happened when you're breastfeeding and there's nobody in the house [...] it's much more problematic and it takes more time to get the baby out get dressed and go to open the door.*" (P6 breastfeeding parent). Likewise, many participants could relate to the workplace scenario, e.g., "*At work, I was not breastfeeding but pumping, and of course someone knocked. So it happens. [...] I'm quite OK with it but I imagine people might feel not very comfortable with that, so this thing happened but it shouldn't happen but the fact that you're in a meeting room it's not an ideal situation either I think there should be a room that I can do it at your own time or at your own speed. But it happens.*" (P8 breastfeeding parent).

Finally, we would like to note that there were no instances in our data that suggested that users got overwhelmed or discouraged by the virtual experience, but that - as illustrated by the quotes included above - they viewed challenges in context and leveraged the simulation as a point for further reflection.

5.4.2 Micro-Frictions that Hinder the Conveyance of Breastfeeding Experiences. This theme captures instances in which participant expectations and features of the simulation did not align. We refer to these instances as *micro-frictions*, i.e., aspects that interrupted the experience and immersion. We observed that these frictions fell into two main categories, frictions that are related to the look and feel of the simulation, and frictions that are caused by a lack of interactivity.

With respect to **micro-frictions caused by the look and feel of the simulation**, participants specifically pointed out mismatches between the virtual character and themselves, e.g., "*I know that it's not me. <laugh> I cannot relate the body because I know I'm bigger.*" (P3, breastfeeding parent), highlighting the need for further customisation. This was also reflected in feedback from participants who wished to be able to adjust the skin tone of baby and parent separately. Interestingly, there were no negative remarks associated with the virtual representation of baby, apart from the comments that the virtual baby is smaller than real life babies. This suggests that the fairly neutral, stylised baby served as a blank canvas that allowed parents to project their views and ideas. With respect to the design of the environment, the majority of participants appreciated the pristine look of the virtual environment, particularly

the scenario taking place in the personal living space. However, participants noted that the room looked *"very clean"* (P1, P6, P9) and pointed out that "*if you have a newborn at home you don't always have the time to clean*" (P8).

Micro-frictions caused by a lack of interactivity predominantly relate to the behaviour of the baby, and the level of fidelity at which the latching process is portrayed. For example, participants pointed out that some breastfeeding aspects were not presented, more specifically, "*in reality there is a little bit more wiggling with the baby, like making sure that you are holding their head in the correct way that it supported, and sort of manipulating also manipulating the nipple, to make it all match*" (P6 breastfeeding parent). Likewise, while many participants appreciated the slightly distanced presence of a partner answering the door, one participant whose partner was very engaged in breastfeeding pointed out that it was awkward that the agent in the simulation did not engage in closer interaction, suggesting she had hoped for a more interactive experience. This notion was reflected in general comments on the presence of non-player characters in the simulation, with a small number of participants suggesting that agents could have approached users more closely to increase the potential to experience a sense of awkwardness when feeding in public. However, other participants directly contradicted this suggestion, pointing out that *"I think I underestimated my feeling a bit awkward about it and feeling a bit in public, feeling exposed."* (P5 parent-to-be). Beyond these straightforward examples of friction caused by a lack of interactivity, **another source of friction was rooted in the absence of explicit feedback for users**. Here, participants recommended providing explicit feedback in terms of the feeding process rather than favouring nuanced experiences that covey uncertainties throughout the feeding process, for example, adding game elements (P6), tutorials (P2, P3), pop up messages (P2) providing extra information about breastfeeding (P3) or making the baby's hunger cue more pronounced to teach future parents (P8). Finally, one overarching and controversial cause of friction was **the absence of elaborate haptic feedback in our simulation**. For example, one participant suggested that "*you don't have the experience of skin to skin, and you're still dressed and that's a bit different.*" (P6 breastfeeding parent). Along the same lines, a partner pointed out that "*I'm surprised how little pain there was. <laugh> Because there wasn't any like haptic feedback [...] I remember like it's being a big part of breastfeeding, and I saw that you even have it as one of the educational note at the end of the scenario.*" (P9).

Generally, we want to point out that there was little consensus among participants as to what was considered a source of friction, with numerous instances of contradictory perspectives. This suggests that triggers for micro-frictions are highly individual, something which we speculate is linked with the fact that breastfeeding experiences are likewise unique, with the lived experience of breastfeeding vastly differing among parents.

6 DISCUSSION

In this section, we summarise our key findings to answer our research questions. We further discuss the potential of breastfeeding simulations to spark *nuanced* reflection, and we highlight key challenges for the design of early parenthood simulations that we observed on the basis of our research.

RQ1: What design considerations need to be made when creating interactive simulations to convey the lived experience of breastfeeding and associated challenges? Based on our research, we can conclude that simulations of breastfeeding need to be designed with care to craft a nuanced picture of positive and more challenging aspects, providing a realistic yet balanced view on what breastfeeding is commonly like (e.g., initial difficulties when latching the baby, or introducing the user to breastfeeding in public). Here, our research suggests that only hinting at challenges contributed to reflection among users, while avoiding overwhelming them. Therefore, we conclude that - in sensitive settings such as early parenting - it may be beneficial to remain vague in the design of scenarios, providing starting points for reflection, but also leaving space for the imagination of the user. Additionally, our results suggest that it is particularly important to be aware of the relevance of customisation and the individual experience in this setting: in our design sessions, participants widely highlighted the relevance of partner support, but individual family situations may vary, and emphasising sources of support not available to an individual risk a discouraging experience. Likewise, the home environment of users may differ from what is presented in the simulation, potentially creating a disconnect between simulation and reality, highlighting the need for customizable simulations which we discuss in section 6.2.

RQ2: How do parents and parents-to-be perceive an interactive simulation of breastfeeding, and what is its potential for antenatal education? Our results suggest that the participants were generally enthusiastic about the simulated experience, which they found engaging. Notably, many participants highlighted how it sparked reflection, and highlighted the challenges of breastfeeding, but not in a way that was perceived as discouraging. Throughout, we observed moments of bonding between parents and the virtual baby, highlighting the potential of the simulation to foster relatedness and also convey positive elements of breastfeeding. With respect to challenges, we saw differences in parents' perceptions of the level of difficulty of our simulation, with those who were experienced in breastfeeding suggesting the inclusion of further challenges, while other participants found the simulation more difficult than expected, particularly those who had no experience in breastfeeding. In terms of the integration of interactive simulations in antenatal education, our results emphasise the potential of VR to allow users to get a glimpse of the lived experience of breastfeeding. Here, participants suggested that the simulation not so much conveyed the technicalities of breastfeeding as it allowed them to explore wider challenges that resulted from the practicalities of breastfeeding in different scenarios, and let them reflect on implications for their own expectations and behaviours. Therefore, we conclude that our simulation could support antenatal education as a means of encouraging reflection, a process that we discuss further in the next section.

6.1 Leveraging Immersive Technology as a Tool for Reflection in Sensitive Settings

Our work focused on capturing the lived experience of breastfeeding through interactive simulation, addressing a personal and sensitive topic. It provides a case study of an interactive simulation that

serves as a starting point for reflection, i.e., provoking thoughts that challenge the initial understanding of the lived breastfeeding experience, rather than a tool for instruction and knowledge provision. In our context, designing for reflection is valuable to encourage users to engage in basic reflection, probing their own experiences and assumptions, potentially facilitating *transformation*, i.e., the highest form of reflection that leads to the adjustment of one's assumptions or behaviours (e.g., see [9, 10, 71]). While a recent examination of reflection in the context of digital games highlighted limitations of interactive technology to trigger transformative reflection [51], our work provides evidence that it may be possible to design interactive simulation in a way that sparks it, especially for parents-to-be and parents who already find the topic relevant. However, the design of our simulation challenges common game design practice of providing guided and goal-directed experiences. This is in line with Khaled's work [40] on reflective game design that calls for open-ended experiences that encourage meta-level engagement: Where games and simulations frequently strive to provide users with hyper-realistic experiences (e.g., see [16, 43]), there were several instances in which we opted for intentionally vague design [40]. Appreciating the highly individual relationship between parent and child, we did not provide users with a high-fidelity virtual baby and remained visually vague to give room to the user's imagination. Likewise, the simulation only hinted at certain aspects, e.g., presence of a partner or colleagues, reminding users of their potential roles, but also leaving room for reflection. In addition to vagueness, we only opted for a small number of firmly scripted environmental events, creating a slow-paced experience that allowed users to otherwise freely allocate their time and fully focus on the virtual baby. While interacting with the baby of course placed demands on users, we hypothesise that otherwise giving them space, both in terms of visual and interactive elements, contributed to a calm experience that facilitated bonding with the virtual baby. This further highlights the potential of open-ended interactive experiences that prioritise *"questions over answers"* [40], where intentional vagueness and slow-paced simulation can act as vehicles that allow users to imagine individual experiences within the virtual environments provided, thereby creating space that is needed to initiate meaningful reflection.

6.2 Capturing Lived Experience Through Simulation: Challenges for Design

While our simulation largely provided users with engaging experiences, we also observed a number of challenges for the design of technology that draws from people's lived experience in sensitive settings, which we further discuss here.

6.2.1 What can, and what should be simulated? Lived experience can be complex, emotional, and potentially upsetting. This also holds true in the context of our simulation, with breastfeeding being a painful, emotionally challenging experience for many parents [73]. While previous work articulates a need to prioritise *disruption* over *comfort* in an effort to create interactive experiences that trigger reflection [40], we argue that this is a balancing act when designing for sensitive settings. As such, we align with Baumer's view [9], who questions whether reflection is always desirable. While his argument primarily addresses reflection on one's own past experiences and the value of forgetting (cf. [10], p88-89), we adopt a forward-looking perspective where systems need to avoid the discouragement of future behaviours. In our case, we assume that this would be the case if the simulation is overwhelming. However, not addressing all challenges of breastfeeding may convey an incorrect, falsely positive experience of early breastfeeding. In the case of pain experienced during breastfeeding, its practical inclusion of pain in our simulation would have either required a haptic element, which we deemed inappropriate or explicit, real time messaging, which we wanted to avoid for reasons discussed in 6.2.2. Instead, we decided to insert short information screens at the end of each scenario, clearly articulating the limitations of the simulated experience, which we suggest a strategy to reveal aspects of lived experience that are either challenging or not appropriate to be simulated.

6.2.2 How can users be supported in holding tension that results from uncertainty? Our results suggest that uncertainty experienced within the simulation (e.g., about breastfeeding progress) led to micro-frictions, which participants suggested could be resolved by additional feedback akin to what is typically provided in games (i.e., continuous feedback on the status of the game). While this may be perceived as a weakness of the simulation, we want to note that real-world breastfeeding comes with the very same uncertainty, which in fact is one of the core challenges for new parents [41]. Hence, we believe there is value in encouraging users to hold this tension and experience uncertainty, but there are two aspects that need to be taken into account. First, we recognise that expectations of users who are familiar with games may need to be addressed with more nuance. Second, the amount of uncertainty needs to be carefully selected so that the tension induced is justifiable and can provoke discussion about uncertainty in breastfeeding. We argue that the uncertainty needs to be embraced and conveyed as a core breastfeeding challenge while feedback can be provided implicitly relevant to the context, e.g., through slightly exaggerated animations, sound and visual effects.

6.2.3 How can the risk of simulations reinforcing norms and stereotypes be addressed? We believe that it is important that researchers and designers understand the extent to which their own values (and, in the case of co-creation, also those of co-designers) transpire into virtual worlds, potentially reflecting societal stereotypes and norms. For example, the simulated home environment in our simulation suggests both wealth and that it is possible to inhabit a very tidy home while caring for a newborn baby. However, in reflection, evaluation participants commented that this was not their reality. While this may seem to be a small inaccuracy or funny anecdote in hindsight, there already is significant pressure on new parents to maintain polished homes while also looking after a newborn baby that often leads to stress [26]. Additionally, the simulation makes assumptions about family composition, body type of the breastfeeding parents and that breastfeeding involves feeding a child directly from the breast (rather than bottle-feeding expressed milk), creating another instance in which users are confronted with normative expectations. To reduce the risk of reinforcing norms and stereotypes, we therefore recommend offering a high degree of customisation that can mirror the users' reality.

7 LIMITATIONS AND FUTURE WORK

There are a few limitations that need to be taken into account when interpreting our findings. Large parts of this research were carried out in Western Europe. Assuming that experiences of parenthood and breastfeeding have a cultural dimension, caution needs to be exercised when generalising findings of design sessions and the evaluation to other populations. This applies to the scenarios that are included in the final simulation, which reflect a wealthy lifestyle (either because desired or experienced) and are not representative of everyone. From a methodological perspective, because design workshops were held online, the initial prototype could only be showcased through videos, rather than individual, hands-on exploration by participants. Furthermore, we consider it a limitation that design workshops were done in pairs or individually (in response to the Covid-19 pandemic) and in turn, comprehensive discussion among participants was not possible. However, allowing participants to take part remotely reduced access barriers to our research, and allowed participants to reflect upon potentially sensitive issues from the comfort of their own home.

We see several avenues for future work. First, we plan to carry out a larger-scale quantitative evaluation of our system with parents-to-be without breastfeeding experience that studies whether the simulation can convey realistic perspectives on breastfeeding. This would offer an opportunity to work with a larger number of parents-to-be, something which we opted not to do at scale in this initial piece of work as we first wanted to examine whether the simulation provides an appropriate, nuanced experience. Additionally, exploring the simulation with other stakeholders, e.g., architects or policy makers, could provide insights into its potential to contribute to the design of a breastfeeding-friendly built environment. Finally, the work presented here provides ample pointers for future development of our simulation, for example, increasing the fidelity of breastfeeding interactions, creating options to tailor the system to different family compositions and breastfeeding modes, and the integration of more interactive non-player characters.

8 CONCLUSION

Breastfeeding can be a challenging experience for new parents, who often have limited insights into the lived experience when they enter parenthood. In our work, we have demonstrated the potential of an interactive and immersive Virtual Reality simulation to provide an opportunity to explore breastfeeding a baby in different scenarios, offering concrete challenges (and positive moments) as starting points for reflection, while also highlighting the influence of other persons and the built environment on the experience of breastfeeding. Results of our work highlight that such simulations can provide an engaging and stimulating experience that showcases some of the practicalities of daily breastfeeding, extending beyond existing approaches of leveraging technology as a means of conveying factual knowledge about the process of breastfeeding [72]. Thereby, our work serves as a first step toward the creation of technology that supports the transition to parenthood by centring the lived experience, acknowledging that a positive breastfeeding experience does not only hinge on the acquisition of theoretical knowledge, but also requires parents to develop realistic expectations of and practical approaches toward feeding their child. Here, we hope that our work can encourage and support the further development of experiential technology that supplements existing efforts in antenatal education, and that is mindful of the sensitive, intimate nature of the deployment context.

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