Proceedings of the Design Society, Volume 5: ICED25
https://doi.org/10.1017/pds.2025.10308

# Supporting parent-child bonding and attachment practices in the NICU: designing and evaluating a non-intrusive health monitoring solution

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**ABSTRACT:** This research addresses the critical need for designing alternative healthcare monitoring systems that support health benefiting parent-child interactions during hospital stays, especially in neonatal intensive care units (NICUs). We developed a HIPAA-compliant, remote healthcare monitoring system designed to facilitate positive interactions between parents and their infants such as skin-to-skin contact. To evaluate the proposed system, we conducted a proof-of-concept experiment using video and sensor data collection to assess the system's feasibility and usability with adult participants. Additionally, we examined participants' subjective experiences through post-interaction surveys and interviews. Overall, the system was perceived as helpful in supporting caregiver-patient interactions. Future improvements can address concerns about continuous monitoring and data management.

**KEYWORDS:** systems design, health monitoring, caregivers, neonatal care

## 1. Introduction

Family caregivers comprise over one in five Americans (NAC and AARP, 2020). The role of caregivers in health care is essential, as they provide emotional and social support. However, caregivers require access to resources and support to maintain their own well-being and that of those they care for (Adib-Hajbaghery and Ahmadi, 2019). The growing recognition of caregiver burdens and their impact on patient outcomes highlights the need for targeted interventions to support caregivers (Stromberg, 2013). When caregiving involves children, parents and close family members play a crucial role as engaged proponents of and stakeholders in patient health. Caregivers actively contribute to their children's health and development, especially during hospitalizations. Parents' involvement in pediatric care fosters more humanized and improved quality of care delivery, which can support long-term recovery for hospitalized children (Nikkhah et al., 2022). However, many parents report feeling excluded from the caregiving process and express dissatisfaction with communication from their children's healthcare providers (Hall et al., 2016, Cooper et al., 2014). Furthermore, hospital stays often expose parents to significant stress, which can negatively affect parent-child bonding and lead to poorer long-term health outcomes for children (Hall et al., 2016).

Several practices aim to promote parent-child bonding, with one notable method being Kangaroo Care (KC) (Sabnis et al., 2019). KC involves skin-to-skin contact where infants are continuously held by a caregiver, fostering attachment through physical closeness, eye-to-eye interaction, and even caregiver-infant synchrony between temperature and breathing rate (Clarke-Sather et al., 2024). While KC has demonstrated significant health benefits for both parents and children, its implementation in hospital settings is difficult. For example, KC implementation may involve coordination among multiple caregivers (e.g., nurses, doctors, and parents), which can complicate its effectiveness in supporting parent-child connection (Hall et al., 2016). To enhance parent-child bonding and facilitate attachment-promoting practices like KC, there is a need for research about the design of alternative systems to monitor such behaviors effectively in hospital environments (El-

Farrash et al., 2020, Joglekar et al., 2018) without burdening caregivers with more work such as recordkeeping (Naylor et al., 2020).

This study aims to address this critical gap by designing an alternative healthcare monitoring system that can efficiently support interactions between the parent-child dyad during hospital stays, particularly in neonatal intensive care units (NICUs). Through the collaboration of a multidisciplinary research team - medical researchers, computer scientists, design engineers, we developed a HIPAA-compliant, non-intrusive health monitoring system to document, and ultimately encourage, positive parent-child interactions (Carlson et al., 2023, Pemble et al., 2024). To evaluate the system's feasibility and usability, we conducted a proof-of-concept experiment in a controlled lab environment with only adult participants to gather their feedback and attitudes toward the system. To guide this research, we propose the following questions:

- **RQ.1:** *What is the feasibility of implementing a HIPAA-compliant, non-intrusive health monitoring solution in a controlled NICU-like environment?*
- **RQ.2:** *How do people perceive the usability and practicality of the proposed system?*

### 1.1. Case Study: Neonatal Intensive Care Units (NICUs)

In 2023, approximately 1 in 10 babies (10.4% of live births) in the United States were born preterm (March of Dimes, 2024). Preterm infants frequently require specialized medical care in NICUs. The NICU environment can be profoundly stressful, with both infants and caregivers frequently enduring traumatic experiences (Sabnis et al., 2019). Parental involvement in the NICU is vital for aiding infants' recovery from traumatic experiences. Parents play a central role in caregiving tasks, such as milk expression, which are often integral components of care plans prescribed by healthcare providers. However, caregiving responsibilities demand significant time, effort, resources, and the maintenance of the parent's health (Carlson et al., 2023, Naylor et al., 2020). In particular for mothers, NICU experiences can adversely affect their ability to perform caregiving activities, attend to their own physical health, bond with their infants, and may ultimately impact the infants' health (Davies et al., 2021). Therefore, identifying effective and efficient strategies to support parents in their caregiving roles is essential, as such support can significantly enhance infants' health outcomes, and has the potential to mitigate or even eliminate the negative effects of prior trauma (Grande et al., 2022).

## 2. System Design

We developed a HIPAA-compliant, non-intrusive health monitoring system designed with a focus on accuracy and caregiver's comfort. In particular, previous literature, e.g., (Joglekar et al., 2018, Clarke-Sather et al., 2024), and previous work, e.g., (Clarke-Sather et al., 2018, Clarke-Sather and Naylor, 2019, Carlson et al., 2023, Pemble et al., 2024) informed the following design requirements for caregiver-patient dyads: wireless, automatic, secure/private, and ease of use. A contextual design theory approach towards system design (Wixon et al., 1990) was utilized when collecting information through interviews and survey from mothers and hospital staff (nurses, doctors, respiratory and physical therapists among others). Through thirty-three ad hoc meetings involving different groups of researchers held in person or on zoom between May 2022 and November 2024 additional stakeholder input besides the caregiver-patient dyad from medical researchers (n=9), computer scientists (n=6) and design engineers (n=4) was gathered. Over time these stakeholders defined the following requirements to ensure precise measurements while maintaining the comfort and well-being of both patient and caregiver: portability and compatibility, mobility, time-synchronization, pertinent medical information, and ease parsing outputs.

### 2.1. Design Process

We followed an iterative and incremental design methodology, a common software engineering approach (Larman and Basili, 2003), to inform both software and human-computer interface design for this system. We started by developing the vital signs monitoring component to avoid disrupting caregiver-child bonding, enabling seamless data collection with minimal effort from caregivers or healthcare professionals (Carlson et al., 2023). Next, we developed and tested a secure and HIPAA-compliant software to safeguard the privacy of both caregivers and children (Pemble et al., 2024).

Finally, we expanded the proposed monitoring system to include: a smartphone with a Wi-Fi hotspot and geolocation capability, facial tracking cameras, a computer for data storage and external data transmission, and a signal trigger to initiate video capture. Below, we explain each module of the system in detail (see Figure 1):

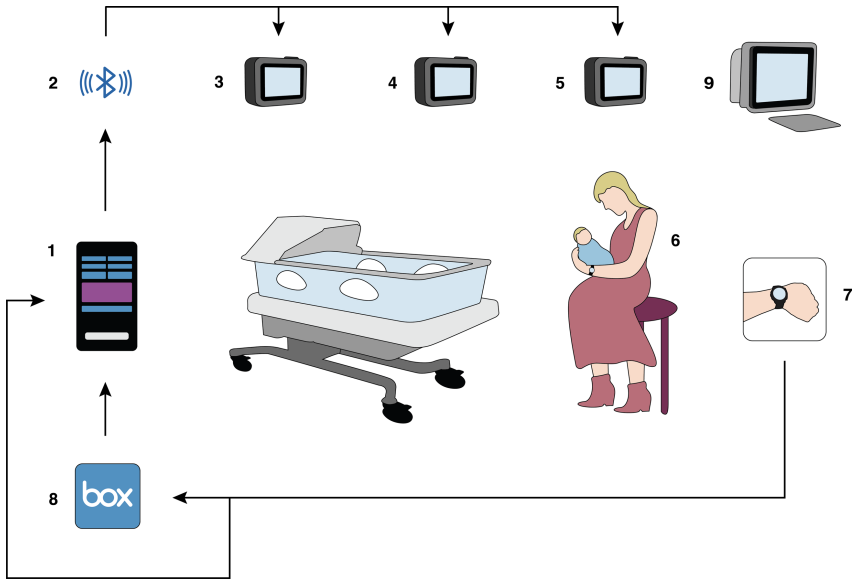


**Figure 1. Caregiver-Dyad Health Monitoring System (Uphus, 2025) 1) Android Mobile App 2) Cameras turned on by Geolocation 3,4,5) GoPro cameras 6) Caregiver & Infant Patient 7) Smartwatch - caregiver vitals monitor 8) Data uploaded to Box Secure Storage 9) Infant Vitals Monitor**

1. **Android Mobile App.** We developed a mobile application to track the caregiver's location upon arrival at the hospital using geolocation, monitor KC interactions, and collect feedback. The system is designed to simultaneously activate camera control due to geolocation functionalities. To assess app performance, we integrated Google Analytics, focusing on key metrics such as average user engagement, user activity, and event count. After each KC session, caregivers receive an online Qualtrics survey (e.g., usability survey (Koester et al., 1998)) to provide feedback (see Figure 1 - Step 1).
2. **Cameras Turned On by Geolocation.** The video monitoring system is automatically activated once the caregiver enters a 10-meter Bluetooth range at the hospital; thus guaranteeing the system only collects data when both caregiver and patient are present. We utilized Google's Fused Location Provider for Android (Google, 2024) a service that enables accurate location tracking of participants (see Figure 1 - Step 2).
3. **GoPro Cameras.** We employed GoPro cameras alongside the GoEasyPro Android software (Konrad, 2024) to record KC interactions. Additionally, facial-tracking cameras capture caregiver-child behaviors, such as eye contact, skin contact, and vocal interactions (see Figure 1 - Steps 3, 4, 5). To ensure reliability, the system automatically sends an email notification to researchers if any camera unexpectedly turns off due to technical issues.
4. **Caregiver-Infant Interaction Monitoring.** Throughout the hospital stay, the monitoring system continuously tracks caregiver-infant KC interactions with minimal disruption.
5. **Smartwatch Integration.** We selected the Garmin Venu® Sq and Garmin Venu® Sq 2 smartwatches to collect vital sign data, including heart rate (see Figure 1 - Step 7). While in the hospital, caregivers' vital signs are continuously monitored through the smartwatch (Carlson et al., 2023).
6. **Data Storage.** A custom software solution was developed to transfer Garmin-acquired data to a HIPAA-compliant Box Secure Storage folder (Pemble et al., 2024) (see Figure 1 - Step 8). Data is transmitted via Bluetooth and 4G Wi-Fi from the smartphone to a secure computer folder.

7. **Infant Vitals Monitoring.** We plan to integrate our system with the hospital's clinical monitors to collect real-time vital sign data from infants (see Figure 1 - Step 9). In this way, time-synchronized comparison of caregiver-patient interactions' impact on caregivers and patients' vital signs can be made.

# 3. Methods

We have conducted a proof-of-concept experiment in a controlled lab environment with only adult participants to evaluate the effectiveness and feasibility of using the proposed system. Additionally, we examined participants' subjective experiences through post-interaction surveys and interviews.

## 3.1. Study Design and Recruitment

This study received approval from the UMN Institutional Review Board (IRB) prior to the initiation of any research activities. Participants were recruited locally through a combination of flier postings (e.g., at the library and on bulletin boards around campus) and word-of-mouth referrals. The inclusion criteria specified that participants must be: (a) 18 years of age or older and (b) currently enrolled at UMN (e.g., students, staff). Recruitment continued until thematic saturation was achieved, defined as the point at which no new themes emerged during data analysis. Participants engaged with the system for approximately 40 minutes and received $15 as compensation upon completing the study. Each session was conducted in person, with the interaction phase followed by a 10-15-minute interview.

## 3.2. Data Collection

For the experiment, the researcher met participants in a location close to our lab. At this point, participants were loaned a Garmin Venu® Sq smartwatch, which they used throughout the intervention to monitor vital signs such as heart rate, stress level, epochs to breath, and energy level through Garmin's Body Battery™ values. From there, the researcher accompanied the participants to the lab, where the main study activities were conducted. Upon arrival at the lab, participants received a printed outline of the experiment's procedures, and the researcher verbally explained the steps involved. Once participants have given their verbal consent, they were introduced to the baby doll, which they held close to their chest to simulate KC. The session began with participants walking around the room while talking to the baby. This was followed by sitting in a rocking chair where they sang a lullaby to the baby, accompanied by soothing background music. Throughout these activities, synchronized video recordings were captured using multiple GoPro cameras positioned at different angles. To test the system's effectiveness at night time, the lab lights were dimmed. During this, participants were asked to place the baby in a baby carrier and continue interacting by walking around the room, alternating between dark and brightly lit conditions for one minute each. The cameras continued recording these interactions to capture data under different environmental settings. The researcher monitored the cameras to ensure they were functioning correctly, including turning off the cameras to confirm the email alert functionality was working. After the interaction session concluded, participants completed a Qualtrics survey on the mobile application to provide feedback on their experience. The survey contained usability questions (Koester et al., 1998), and user satisfaction and privacy concern questions from Qualtrics sample data. This was followed by a short interview (10-15 min) conducted by the research team to gather more insights into participants' perceptions of the experiment. Some sample questions from the interview are: *"Imagine that you are a parent. Now consider how comfortable you would feel about the collection of your infant's vital signs data for monitoring purposes."* and *"Based on your experience, what potential improvements would you suggest for the future development of this system?"* Upon completing the survey and interview, participants received compensation for the time spent participating.

## 3.3. Data Analysis

We adopted a mixed-method approach to data analysis, combining qualitative insights to deepen the understanding of quantitative findings (Wisdom and Creswell, 2013). Quantitative data was collected through a survey designed to assess the system's usability and feasibility. For qualitative data, semi-structured interviews were conducted (Braun and Clarke, 2013). An inductive qualitative analysis

approach was employed, with the research team open-coding transcribed interview recordings to identify emergent themes. Transcriptions were generated using the third-party service Parrot AI[1]. The identified themes were discussed and refined collaboratively to extract key, high-level insights, focusing specifically on the system's usability and performance during the intervention.

# 4. Results

A total of 30 adults participated in the study. Among them, 9 participants identified as male and 21 as female. The age range was 18-59 years old ($M$ = 22.9, $SD$ = 7.97). 25 participants were enrolled as undergraduate students, 3 were enrolled as graduate students and 2 were staff members. Finally, 17 participants reported having prior experience with children.

## 4.1. Quantitative Results

### *4.1.1. System Usability and Overall Experience*

On a 7-point Likert scale, from 1= "strongly disagree" to 7 = "strongly agree", participants evaluated the system design, usability, and reported their overall experiences participating in this proof-of-concept experiment (Table 2). 63% (19 out of 30) participants responded Strongly Disagree and 30% (9 out of 30) participants responded Disagree (M=1.38, SD=0.55) that using the system was a frustrating experience. In particular, participants reported that they received clear information on what type of data the system collects (M=6.4, SD= 1.2) and on the types of vital signs data used in the system (M=6.5, SD= 0.85).

**Table 1 Survey Results on System Usability**

| Category (n=30) | M | SD | Opinion |
|---|---|---|---|
| System was easy to use | 6.63 | 0.66 | Strongly Agree, Agree |
| System interaction was pleasant | 6.2 | 0.98 | Strongly Agree, Agree |
| Understanding of tasks | 6.13 | 0.85 | Strongly Agree, Agree |
| Capable of using the system with a baby | 6.13 | 0.96 | Strongly Agree, Agree |
| Encountered any issues or bugs | 1.6 | 0.76 | Disagree, Strongly disagree |
| System speed | 2.17 | 1.21 | Disagree, Strongly disagree |
| Frustration using the system | 1.38 | 0.55 | Disagree, Strongly disagree |
| Accuracy of Measures | 5.9 | 0.98 | Neutral, Somewhat Agree, Agree, and Strongly Agree |
| Reliability of data captured | 5.73 | 1.18 | Neutral, Somewhat Agree, Agree, and Strongly Agree |
| Clarity of data collection info | 6.4 | 1.2 | Somewhat Agree, Agree, Strongly Agree |
| Clarity on types of vital signs data used | 6.5 | 0.85 | Somewhat Agree, Agree, Strongly Agree |

### *4.1.2. User Satisfaction*

On a 11-point Likert scale for greater nuance in response, from 0= "extremely dissatisfied" to 10 = "extremely satisfied", participants responded that from their interactions with the system they were slightly to extremely satisfied with system performance (M=8.32, SD=2.06), the system's ability to facilitate bonding and attachment between caregivers and patients (M=8.24, SD=1.73), and their comfort in terms of privacy and personal space during the experiment (M=8.59, SD=1.97) (Table 2).

**Table 2 Survey Results on User Satisfaction**

| Category (n=30) | M | SD | Opinion |
|---|---|---|---|
| System performance | 8.32 | 2.06 | Slightly to Extremely Satisfied |
| System facilitates patient-caregiver bonding | 8.24 | 1.73 | Slightly to Extremely Satisfied |
| Comfort with privacy/personal space | 8.59 | 1.97 | Slightly to Extremely Satisfied |

[1] Parrot AI: https://parrot.ai/

## 4.2. Qualitative Results

All participants attended the semi-structured interview session at the end on the experiment. Each interview session had one investigator to ask pre-defined open-ended questions. Participants' comments were systematically categorized into the following three themes for further improving the system design.

### 4.2.1. Supporting Bonding Practices through Non-Intrusive System Design

Participants highlighted that the non-intrusive design features of the system, such as automated controls via smartphone, smartwatch tracking, and video recording for monitoring interactions, were beneficial in supporting caregiver-patient interactions: *"I like the system because it didn't interfere with anything that I was doing with the baby, and it made it feel like a very personal situation." (P10)* However, 30% of participants reported feeling self-conscious about being recorded, which could influence the caregiver's behavior toward the patient: *"I felt that having a camera and being recorded made me more conscious about how I am with the baby, which is something I was not comfortable with." (P22)*

Participants mentioned that the discomfort on being recorded might also increase the caregiver anxiety, potentially leading to outcomes contrary to the system's intended benefits: *"I think if I was like worried about what results it was giving, then it would be a hindrance. Like if I was trying to have my heart rate at a certain level or something." (P5)* To address these concerns, participants recommended offering clearer explanations and reassurances about how video and vital sign monitoring contribute to improved caregiving outcomes. This approach could help alleviate their discomfort and reduce anxiety about being recorded. Additionally, participants suggested positioning cameras in less noticeable locations within the room to make caregivers feel more at ease. As participant P6 noted: *"I would be more comfortable with them [cameras] if they were to able to remotely monitor us via vital signs and other things like that rather than like a video camera being noticeable in the room." (P6)*

Finally, participants appreciated the physical comfort of using the carrier and the calming effect of the music during the interaction, suggesting that the system enhanced their ability to engage smoothly with the patient during the study's activities. Still, participants mentioned that instead of using a carrier, the caregiver could use a cloth wrap or holding a baby direct on their chest for improved feelings of connection: *"I feel like maybe holding the baby is more active kind of interaction than just having the baby in a carrier."(P17)*

### 4.2.2. Privacy and Data Management Concerns

While the system's design and functionality were generally well-received, privacy concerns emerged as a significant topic during the interviews, particularly regarding continuous camera monitoring during sensitive moments. For instance, participant P2 highlighted potential discomfort for mothers feeding their babies while the system simultaneously monitors interactions, stating: *"So ifwe want to feed the baby, it would be some little embarrassment."(P2)* Similarly, participant 8 described a scenario where privacy issues might arise, noting:

> *. . . imagine your baby is crying or something, you're really frustrated and there's like a camera just recording you. Like the way interact with your kid is definitely going to be way different than how you're going to interact alone. So privacy is definitely something that I feel like it would be a big issue.*

Participants also highlighted the critical importance of robust security measures and transparent communication regarding data usage and storage, emphasizing alignment with HIPAA regulations to build trust among caregivers. Despite these assurances, concerns about potential leaks or misuse of sensitive data, such as vital signs or video recordings, remained prevalent. For instance, participant 20 remarked:

> *I think it's totally understandable for parents to have concern about their child's video being accessible to the healthcare system or if it was potentially hacked. And that's a discussion we've had in my class about the dark side of technology and media. So as wonderful as it is to have the technology to learn about health care and relationships and bonding, it is definitely, I would say, a concern for a wide range of people who don't want their kids faces or information publicly shared.*

### 4.2.3. Parental Role in Caregiving Activities

Our analysis highlights participants' perspectives on the parental role in caregiving activities, revealing a general preference for a co-parenting approach. Participants reflected on their personal experience dealing with caregiver burden and its negative consequences. For example, participant 19 shared his personal experience with gender imbalances in caregiving and their potential impact:

*I feel like the father should also be trying to be as much included into the child's life as much as possible because I know a lot of people, including myself, that never grew up with one, so always the mother. And it's put so much more stress on the mother growing up for the child. So if both the parents are on the same page, just trying to help out each other as much as they can, that would really improve everything*.

In contrast, participant 18 shared an example from his sister's family, where both parents take turns caring for their baby, emphasizing the advantages of shared caregiving responsibilities for both parents and the child. These benefits include stronger bonding and emotional support:

*I have seen my sister got a baby and his father take cares of him very much. In the mornings, my sister take care of the baby and at the nights, when she sleeps, then the father comes and take care of the baby. They take some shifts here and there because I feel like taking care of a baby is not easy. And also I feel if you do it, like take care of the baby, it also affects the parent health. So it's better having like both of them doing it.*

This example highlights the importance of equitable caregiving in promoting well-being for both parents and children. Overall, participants noted that the proposed system could encourage both mothers and fathers to engage in attachment and bonding activities, potentially helping to balance caregiving responsibilities. For instance, participant P1 shared:

*I would strongly recommend this [system] because it's a nice procedure where parents can take care of their babies and sit and relax for some time, and then they feel so soothing, and then maybe even the baby can feel so relaxed. So this kind of setting is really useful to the parents who are taking care of their babies*.

## 5. Discussion and Future Work

Our study explored the feasibility of a non-intrusive, HIPAA compliant health monitoring system designed to enhance parent-child bonding in neonatal intensive care units (NICUs). The proposed system was informed by a contextual design approach towards systems design (Wixon et al., 1990) and followed an iterative and incremental design methodology to split the project's requirements into smaller modules, build the core features of the system, and get early feedback for refinements (Larman and Basili, 2003). Still, we encountered some design challenges such as managing the system integration with the development of new functionality. Conducting early testing, like what we did in this research, has been found to ensure technical feasibility and reveal overlooked issues (Subburaj et al., 2022). Feedback from participants showed that the system effectively supported caregiving activities without significant interference. Participants reported feeling comfortable during the experiment, given the clarity of tasks and easy to use system design. According to our data, the proposed system could facilitate parent-child interactions by unobtrusively monitoring vital signs and behaviors, strengthening findings from similar studies that emphasize minimal disruption in care environments (Carlson et al., 2023, Cooper et al., 2014, Sabnis et al., 2019). Findings from this study could inform future applications in other caregiver-patient dyads, such as aging adults and their caregivers. Additionally, the pilot of this remote vital signs collection system could lead to further understanding of the influence of therapeutic interventions in caregiver-patient dyads, such as between music therapists and their patients(Palazzi et al., 2021, Pemble et al., 2024); music therapy has already shown improvements in vital signs for infants and maternal mental health for infant-caregiver dyads in the NICU (Yue et al., 2021). Due to the successful proof-of-concept shown in this study, this system could be used to develop new interventions that are more synchronized with individual patient's needs, where caregiver-patient interaction is critical and early interventions could promote patient health restoration and mitigate caregiver burden.

Despite the system's benefits, some participants expressed concerns for further design considerations, particularly regarding the system's continuous monitoring capabilities. Although participants indicated they were provided with clear information about the types of data the system collects and uses of this data, participants still worried significantly about being monitored during personal moments. As noted by participant 8, this could potentially disrupt natural parent-child interactions. Previous studies have highlighted similar challenges with the real-time collection of sensitive data, pointing to a broader issue

within real time healthcare monitoring technologies. Specifically, there is an ongoing need to balance the benefits of data collection for health monitoring with the protection of individual privacy rights (Sadek et al., 2019, Sivakumar et al., 2024). Future work could focus on addressing the privacy concerns identified, potentially through enhanced data security protections, user control of when video recording occurs, and greater transparency (Sivakumar et al., 2024). For instance, alongside adherence to regulations such as HIPAA, steps could be taken to provide users with more control over their data, including implementing clear consent mechanisms for third-party data sharing. Additionally, future work could develop more in depth training sessions for caregivers before using a monitoring system to reduce privacy concerns. These trainings would explain how the system collects and uses their data and for what purposes to help users feel more at ease with being monitored and reducing their anxiety about the system (Smith et al., 2017).

Finally, our findings provide valuable insights into participants' perspectives on the role of parents in caregiving. In contrast to studies that primarily depict fathers as providers of financial support, food, and clothing (Rakotomanana et al., 2021), our participants highlighted the importance of co-parenting, emphasizing active and equal involvement of both fathers and mothers in caregiving responsibilities. Personal examples shared by participants emphasized the benefits of shared caregiving for both parents and children, as well as the negative consequences of unbalanced caregiving duties, as illustrated by participants P18 and P19. These insights align with prior research recognizing the caregiver's burden (Adib-Hajbaghery and Ahmadi, 2019, Stromberg, 2013); suggesting that establishing a strong, early bond between parent and child is critical for fostering deeper relationships as the child grows (Davies et al., 2021, Grande et al., 2022). Moreover, sharing caregiving responsibilities has been shown to help caregivers manage stress more effectively, provide better care for their children, and improve their own quality of life (Adib-Hajbaghery and Ahmadi, 2019). Although our study was conducted in a controlled lab setting with only adult participants, we argue that these findings can inspire future investigations into family-centered caregiving models. Specifically, we think that hands-on parental involvement could shift the focus to the family as a cohesive unit, ensuring adequate support for all parents to meet their children's needs, particularly during hospitalization. Future research should investigate the implementation of similar system designs in clinical settings, incorporating feedback from healthcare professionals to evaluate their effectiveness and feasibility for real-world clinical integration.

## 6. Limitations

Our study introduces a non-intrusive, HIPAA-compliant health monitoring system designed to facilitate positive interactions between parents and their infants. We acknowledge the limitations of our proof-of-concept experiment and the preliminary nature of our findings, as it may not fully capture the range of user behaviors. Future research should consider long-term interventions to address these limitations. Additionally, our study is formative, informed by prior literature, and aims to assess the system's feasibility and usability in a controlled environment with a baby doll. Future work should address this limitation by testing the system under more realistic conditions such as in a hospital or home care setting to mimic the dynamic interactions of genuine parent-infant bonding. Finally, while we aimed to recruit a larger and diverse sample of participants, we are aware that our sample size and group may not be representative of the general population. We acknowledge that our sample is limited toward individuals with no prior caregiving experience and potentially bias towards individuals particularly interested in health monitoring tools. We also acknowledge that our study sample size is not enough to conduct statistical analyses, such as significance tests. Additionally, including feedback from healthcare professionals could provide valuable insights into the system's design and clinical integration. Still, our study's sample is consistent with the recommendations for formative research (Braun and Clarke, 2013). Future studies should address these limitations, including a broader spectrum of stakeholders and various types of parent-child dynamics to gain deeper insights and propose innovative health monitoring interventions.

## 7. Conclusions

Our study findings show the feasibility of a health monitoring system to facilitate bonding practices between parents and children in hospital settings like NICUs, while keeping the process simple, comfortable, and private. According to our data, the system was easy to use and would have minimum interference on parent-child interactions, making it a positive experience for participants. We argue that

our proposed system could support important caregiver-infant bonding and attachment practices like Kangaroo Care, and these findings could help improve outcomes in additional medical and therapeutic settings for patient-caregiver dyads. Additionally, we expect that this study's findings could lead to more investigations on how to better deliver dyad- and family-centered care, and potentially shortened recovery times for patients due to more personalized and timely interventions and greater caregiver engagement in their rehabilitation. However, some valid concerns were raised for further design development such as data management and concern about being monitored. We recommend future research focus on the effectiveness of remote health care vital signs monitoring systems in hospital settings and study its short-, medium-, and long-term benefits for parents and their children.

## Acknowledgments

We would like to express our sincere thanks to insights provided by Dr. T. Christina Zhao, Dr. Andrea Cevasco-Trotter, and Dr. Michael Silverman, and all our participants for supporting our work.

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