2024

Cognitive Companion

Designing a cognitive assistant for the bedside nursing practice at the Erasmus MC Sophia.

Master thesis
Victor Verboom

TU Delft
Erasmus MC

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Victor Verboom

MSc Design for Interaction
MSc Integrated Product Design

August 2024

Delft University of Technology
Faculty Industrial Design Engineering

Supervisory team

Chair	Dr. Ing. M.C. (Marco) Rozendaal
Mentor	Dr. J.H. (Jordan) Boyle PhD

In collaboration with

Erasmus MC Sophia Kinderziekenhuis

Prof. M. (Monique) van Dijk PhD
A. (Anne) Heijboer Msc

Preface

This thesis represents my graduation project focused on researching and developing a cognitive assistant for the bedside nursing practice at Erasmus Medical Center. During my search for a graduation topic involving human-centered technology, I met Marco Rozendaal, Jordan Boyle, and Monique van Dijk, who were instrumental in initiating this project. They introduced me to the field of Human-Computer Interaction and the transdisciplinary research collaboration of the Sustainable Health Program. In this preface, I would like to acknowledge and express my sincere gratitude to everyone involved in this project. Your contributions were crucial to both conducting the research and ensuring its success.

Firstly, I am immensely grateful to my project chair and mentor, Marco Rozendaal and Jordan Boyle, for their exceptional guidance and support throughout this endeavor. You have been outstanding coaches, both personally and professionally. Your welcoming and collaborative approach during our biweekly meetings in the Human-Robot Interaction Lab has been truly inspiring. This project would not have been possible without your expertise in Human-Computer Interaction research, technology, and design. Thank you for supporting me through the challenges of researching and designing technology for medical contexts. Your guidance has significantly contributed to my growth as both a person and a designer.

I would also like to extend special appreciation to Monique van Dijk and Anne Heijboer for providing me with the opportunity to engage in the bedside nursing practice and connect with the wonderful people at Erasmus MC. Your support was crucial in enabling me to conduct research within a real nursing environment. Additionally, I want to express my utmost gratitude to all the nurses involved at the Children's Thorax Center at Erasmus MC Sophia. Your participation and cooperation were essential for the research activities and for guiding me through bedside nursing practice, ultimately leading to the findings presented in this project. Thank you for your enthusiasm, passionate input, and for sharing these valuable experiences in healthcare with me.

I also wish to thank all the members of the transdisciplinary research team of the Sustainable Health Program, led by Monique van Dijk and David Abbink. Your support in allowing me to share my findings and for adding greater purpose to this project is deeply appreciated. I hope the findings of this project can further inform research and design development for future technological applications at Erasmus MC.

Finally, I want to express my heartfelt gratitude to my friends and family for their love and encouragement through the challenges I faced during this project. As a designer driven by intuitive curiosity and passion, I might not have achieved what is presented here without your support.

While this thesis marks my graduation, it represents a collaborative effort involving many wonderful people who invested their time and effort into advancing healthcare practices. I hope this report inspires and enriches you as much as it has enriched me during its development.

Executive Summary

Technological innovation can provide valuable solutions for the challenges facing the Dutch healthcare sector. However, the development of such innovations poses transdisciplinary challenges in aligning academic research, practice, and technology. This graduation project addresses those challenges by conducting exploratory design research for the bedside nursing practice at the Children's Thorax Center at Erasmus MC Sophia Children's Hospital.

The initial phase of the project focused on gaining familiarity with the bedside nursing practice to establish preliminary insights for desired changes. Two nurses were shadowed during their shifts at the aforementioned pediatric ward, employing a contextual inquiry research method to gather observational insights and enhance the understanding of bedside nursing. A reflective analysis of practice understanding, established through nurse feedback and observations, resulted in a list of desired transformations within the practice. These transformations were validated and further elaborated upon through a group feedback session with nurses, which culminated in primary design opportunities involving improved local accessibility of medical data for both input and retrieval, interpersonal communication, and memory support.

The second phase focused on further defining strategic opportunities for innovation development and bridging insights from current practice to a design direction for the desired future. The analysis of four practice dimensions relating to tangibility and relativity resulted in 'personal cognitive support for nurses at the bedside' being identified as the most valuable strategic focus for novel technology research and design development. Subsequently, a future perspective of bedside nursing practice was explored through a generative session with nurses, further highlighting the need for cognitive support and technology accessibility at the bedside. This led to a design direction pursuing the development of a cognitive assistant within a future perspective involving pervasive computing.

The third and final phase of the project involved Research through Design development, using a bridging concept for a cognitive assistant named the Cognitive Companion (Coco). Coco is developed as an AI-enabled wearable device, worn in the chest pocket of the nursing uniform, to provide nurses with always-accessible cognitive assistance wherever they go. It features the operational ease of voice control using AI speech recognition, suited for interactions at the bedside. The purpose of Coco as a bridging concept is to facilitate further research and design development in nursing practice toward the realization of the pervasive computing future perspective. To achieve this, a pretotype was built and used in real nursing practice. This revealed that current interventions force nurses to adjust their practice to accommodate technology interactions, which adds extra mental strain by demanding their focus and mental energy during bedside care.

Ultimately, this project concludes that future technological developments for bedside nursing should focus on human interactions and care, which are fundamental aspects that must be safeguarded. Interactions with technology interventions should be simple, easily accessible, and seamlessly integrated into the practice surroundings so that they support rather than distract from patient care. The proposal building on these findings follows a future perspective of pervasive computing in practice, which can be supported through the development of the Coco AI-enabled wearable.

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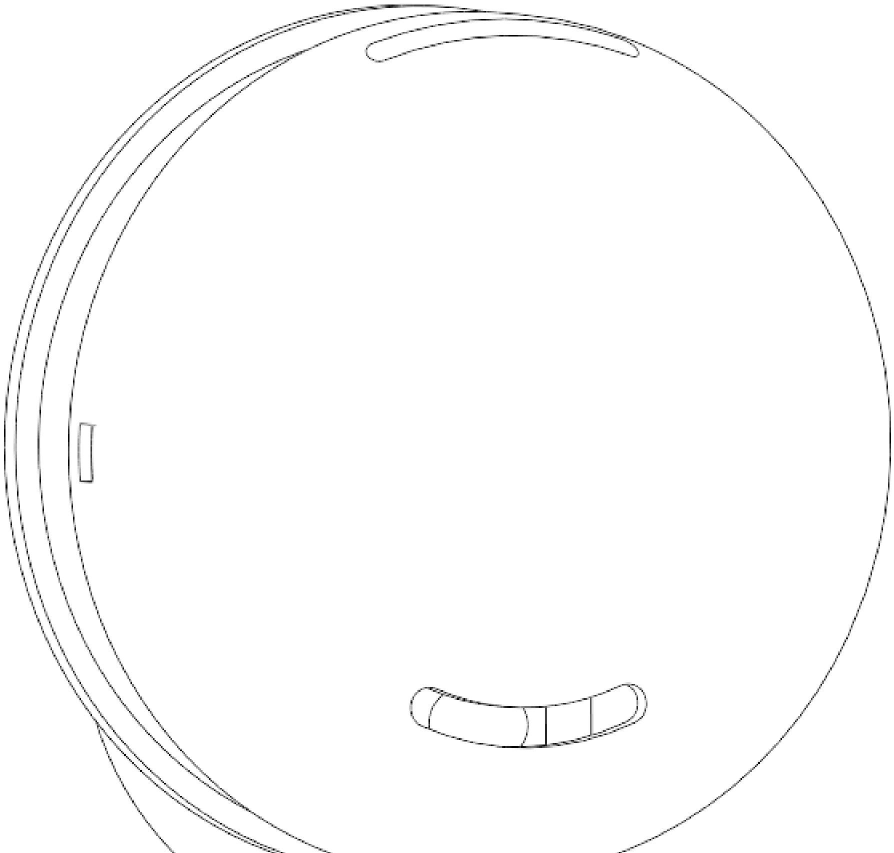
Phase 3 | Design



Chapter 1 | Introduction

This first chapter serves as the introduction to this thesis. It discusses the broader context of technological innovation in healthcare, which inspired and motivated this project. It delves into the history of the term ‘practice,’ establishing its definition and central role in this research. The chapter also defines the project scope by outlining its boundaries, focus, and the main questions the study seeks to address.

Additionally, it introduces all the parties involved in the project, acknowledging their contributions to the successful execution of this extensive research. Finally, it concludes with an overview of the design approach used in this project. This foundational chapter sets the stage for the research activities and analyses that will be presented in the subsequent chapters.

1.1 Technological solutions for healthcare challenges

The healthcare sector in the Netherlands is grappling with staff shortages and increasing workloads (Adams, 2021; CBS, 2022). Moreover, advisory boards and official statistical offices have highlighted alarming projections in their reports to Dutch ministries, indicating a continuing increase in demand for caretakers in the near future (Capaciteitsorgaan, 2022; Sociaal-Economische Raad, 2020). Technological innovations, such as robotics, offer promising sustainable solutions to address these challenges. Existing healthcare initiatives have demonstrated the potential of robotic technology to assist individuals with disabilities, alleviate caregivers' workloads, and enhance patient experiences in hospitals, as seen in Figure 1.

Figure 1: a) Fizzy robot ball (Boudewijn, 2020); b) Hospital Delivery Robot (Meulstee, n.d.); c) Feeding robot (ALS Centrum Nederland, 2018); d) AV1 Telepresence robot (Johnsrud, n.d)

However, the integration of robotic technology in human-centered care presents new challenges. Care practices are inherently spontaneous, social, and emotionally engaging, and the introduction of increasingly intelligent interventions adds further complexity to their effective integration and acceptance within this context.

Moreover, effective technology integration in healthcare requires transdisciplinary collaboration, as it involves people from several disciplines in technology, design, healthcare and organization, see Figure 2. These people have to share resources and effectively coordinate communication and actions to collectively tackle the development process.

The research field of Human-Computer Interaction (HCI) focuses on studying these challenges, becoming increasingly relevant amidst the expanding development of artificial intelligence and the diverse applications tailored to specific contexts. This project will immerse itself in this field of HCI, focusing on the potential applications of robotic-related technologies within bedside nursing practices at hospitals. The initial phase involves a thorough exploration and understanding of current care practices, encompassing the study of individuals, their relationships, and the established customs within bedside nursing. Followed by looking into a future of nursing, discussing the potential roles of integrated technology and the evolution of the practice.

Finally, the project will culminate in the development of a cognitive assistant for nurses, utilizing research-through-design techniques to examine the effects of intervention in the practice and conclude with a design proposal.

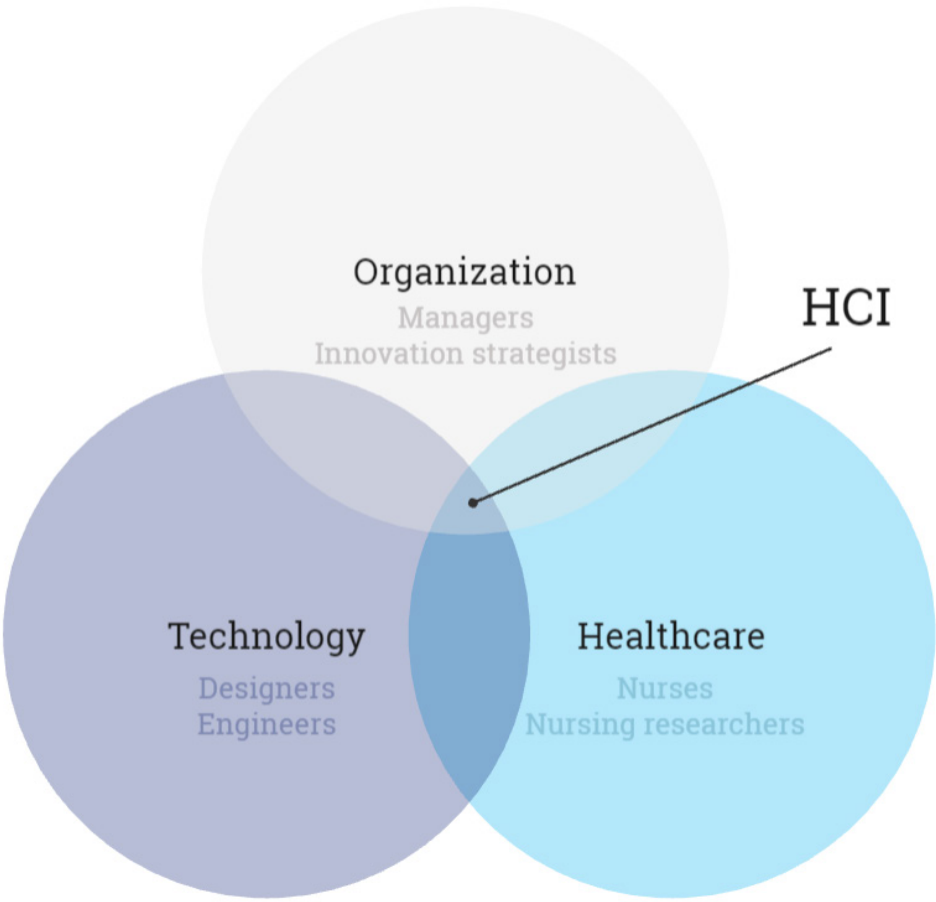


Figure 2: The transdisciplinary challenge and field of HCI in the integration of technology in healthcare.

1.2 Collaborative context

As mentioned in the previous section, the integration of technology into healthcare necessitates transdisciplinary collaboration for successful implementation. This project is no different, as the involvement of various parties has been pivotal in both its initiation and realization. Connections with healthcare professionals have been invaluable for gaining access to the practice and exchanging experienced knowledge about bedside nursing. Simultaneously, regular interactions within research labs have provided essential academic insights, facilitating the execution of both research and design phases of the project.

TU Delft

First of all, the Delft University of Technology (TU Delft) is the main educational institution from which this project was realized. As part of the course MSc Graduation Project at the Faculty of Industrial Design Engineering, this project served as the conclusion of a Double Degree in Master programs, MSc. Design for Interaction (DfI) and MSc. Integrated Product Design (IPD). The support and resources provided by TU Delft were instrumental in facilitating the research and development processes essential to this project's success.

Expressive Intelligence Lab

The Expressive Intelligence Lab is part of the Delft Design Labs, a group of theme-based research labs at the Faculty of Industrial Design Engineering, TU Delft. This lab focuses on creating meaningful and socially appropriate integrations of artificially intelligent products. Throughout this project, the lab has significantly contributed as a knowledge hub, fostering connections with other graduate students and researchers in the field of Human-Computer Interaction.

StudioLab

The research community of StudioLab at the Faculty of Industrial Design Engineering, TU Delft, played a valuable role in assisting with prototyping. They provided assistance in prototyping approaches and supplied the necessary electronic components used in the pretotype.

Erasmus MC Sophia Children's Hospital

The main collaborating healthcare institution involved in this project is the Erasmus Medical Center in Rotterdam. This hospital is the largest university medical center in the Netherlands and a leading promoter of quality healthcare through scientific research and education. This makes the hospital an ideal research context for technological innovation and access to bedside nursing practice. Agreements were established during the initiation phase of the project through the signing of an internship contract with Erasmus MC. This agreement was invaluable in providing access to a medical setting, thereby allowing for the execution of research activities with nurses in the real practice.

Sustainable Health Program

This graduation project was created in congruence with a transdisciplinary research on labor-saving technological innovations, led by Professor Monique van Dijk of the Erasmus MC and Professor David Abbink of the TU Delft. This research program is part of the Erasmus MC Sustainable Health Programs initiative and will be running two years till 2025. As a shorter and much smaller scaled research, this graduation project is created as an initial explorative project for the transdisciplinary research program through the Research through Design approach. The findings and results of this project were regularly shared with the transdisciplinary research team to provide them with added insights for future research and design projects.

The nurses of the Children's Thorax Center

All the research activities were made possible by the participation of the nurses at the Children's Thorax Center at Erasmus MC Sophia, as depicted in Figure 3. A total of 16 children's nurses voluntarily participated in the research activities conducted for this project. Communication with the nurses was facilitated through a nurse researcher who had established contacts within this specific ward. To protect privacy and adhere to ethical guidelines, the nurse participants in this project will not be referred to by personal information, following the informed consent agreements.

Figure 3: The Erasmus MC Sophia Children's Hospital.

1.3 Defining the scope of this project

As suggested by the title of this thesis, the focus of this project revolves around bedside nursing practice at the Erasmus Medical Center in Rotterdam. Before delving deeper into the research, it is essential to establish a clear understanding of what is meant by 'bedside nursing practice'. This section aims to address this by exploring the broader conceptions of 'practice' across various disciplines throughout history and applying these learnings to the specific context of bedside nursing. Ultimately, discussing the project boundaries and defining objectives that attribute to the general aim of this project.

A brief history of 'practice'

The term 'practice' originates from the Greek word 'praxis' and has been a studied phenomenon since the time of Ancient Greek philosopher Aristotle. Aristotle defined 'praxis', as activities whose ends are the actions themselves, which is different to what he referred to as 'peosis', the production towards an end. However, his exact definition and correctness is still being heavily debated by scientists and philosophers until this day, due to his intertwined usage and contradictions (Ackrill, 1978; Balaban, 1986; Belfiore, 1983).

Since then, the term 'practice' has seen countless iterations of definitions and uses throughout the decades in philosophy, being a fundamental principle of Marxism and communistic ideology, as the criterion of truth, or as a key concept in 'being-in-the-world' of Martin Heidegger (Wolff & Leopold, 2020; Wheeler, 2011). Practice is seen as the act of doing, learning and achieving, Interestingly, in these developments troughout history 'practice' seems to have differentiate itself from the original word 'praxis'. This can be seen back in generally conceived definitions in dictionaries nowadays:

> *Praxis: the process of using a theory or something that you have learned in a practical way.*
>
> *Practice: action rather than thought or ideas.*
>
> - *Cambridge Dictionary*

The defintion of practice in this research

It is clear that the phenomenon of 'practice' has been something intriguing and useful, but puzzling to us humans to fully grasp. Unlike its historical conception in philosophy and other anthropological sciences, the term 'practice' will be used here following the HCI conception, as a collective term for the ongoing performance of interactions among people, artifacts, and the situated environment over a period of time, rooted in the social and cultural meanings developed through the history of the bedside nursing profession in hospitals. In this manner, it will be possible to capture the full extent of the design context in action, which is essential for finding alignment with the needs and conditions.

Project boundaries

This project is focused on designing interventions specifically for pediatric nurses at the Children's Thorax Center. Although other participants in the practice, such as patients and physicians, are acknowledged in the analysis, they are excluded from direct involvement in the research and design activities. Initially, the project was established in collaboration with a nursing researcher who has access to an established network of nurses at the Children's Thorax ward. While the potential involvement of other key players, such as child patients, was considered during the early stages of the research, ethical considerations and accessibility challenges led to the decision to focus exclusively on nurses. This approach ensures a targeted and feasible study that addresses the specific needs and perspectives of pediatric nurses.

Research aim and objectives

As mentioned in Section 1.2, Collaborative Context, this project was initially intended as a reconnaissance project for a larger transdisciplinary research program. The decision was made to adopt the following research aim:

The aim of this research is to generate new insights and awareness into designing technological interventions that enhance the bedside practice of pediatric nurses.

The ambitions of the research aim and the focus The ambitions of the research aim and the focus on pediatric nurses at the Children's Thorax Center at Erasmus MC Sophia are combined in the overview presented in Figure 4.

Conducting extensive research on the established practice provides a foundational understanding of potential design opportunities within the current framework. However, the dynamics of a practice typically evolve only when an intervention is introduced. It is through the implementation and application of a design intervention within the practice that actual effects can be observed and evaluated.

Therefore, the research of this project mainly serves as a discovery phase, aimed at gaining a comprehensive understanding and gathering knowledge essential for designing solutions that are grounded in user needs. This is defined in the following research objectives:

To identify design opportunities in the bedside nursing practice at Children's Thorax Center ward.

To define design directions of technological interventions that improve the bedside practice for children's nurses.

To develop a design proposal for a technological intervention that improves the bedside practice for children's nurses.

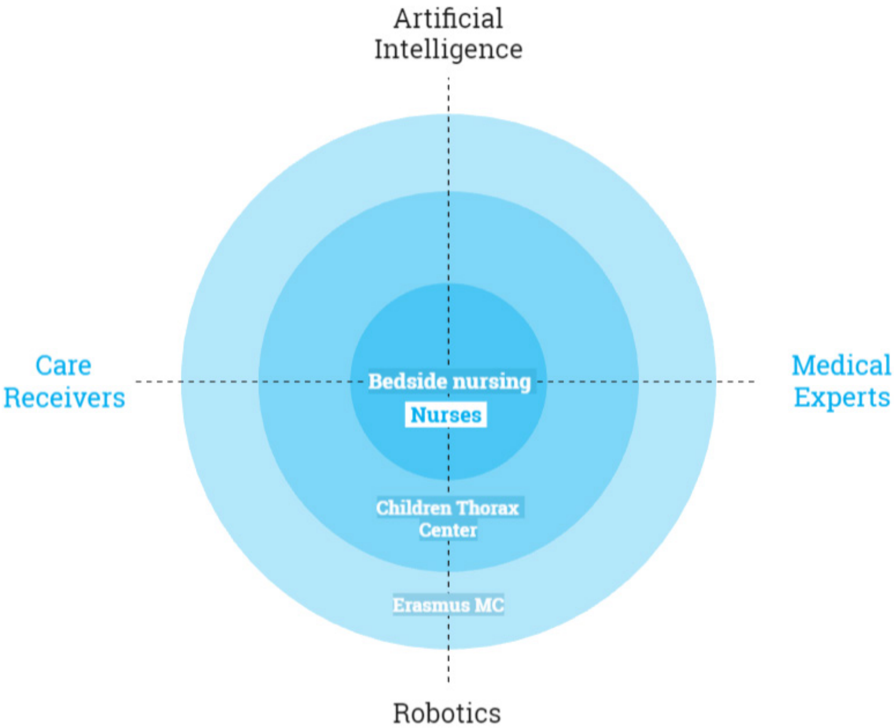


Figure 4: The scope of the project.

1.4 Design approach

Healthcare practices are characterized by unique elements such as specialized terminology and procedures rooted in medical expertise. This complexity poses challenges for designers to become adequately familiarized with these practices, especially for those without medical training or prior experience in healthcare. Moreover, the unpredictable nature of the time required for familiarization and deeper understanding further complicates project planning in this context. However, applying structured design methodologies to such projects proves particularly beneficial as it provides guidance within an unfamiliar terrain. This section will delve into the design approach implemented for this project, illustrating how it facilitated the transition from understanding the healthcare environment to designing solutions that meet the needs of nurses.

Human-Centered Design

Human-Centered Design (HCD) is a problem-solving mindset that prioritizes the accommodation of human needs, capabilities, and behaviors. This approach operates under the belief that centering design processes around human perspectives results in solutions that are better aligned with the fundamental problems grounded in user needs (Interaction Design Foundation, 2021). The International Organization for Standardization (ISO) elaborates on this by stating:

> *This approach enhances effectiveness and efficiency, improves human well-being, user satisfaction, accessibility and sustainability; and counteracts possible adverse effects of use on human health, safety and performance.*
>
> *- ISO (2019)*

An HCD approach generally involves repetitious cycles of observation, idea generation, prototyping, and testing. The goal of such an iterative approach is to facilitate the alignment and understanding of user needs in practice. This method has been found to be particularly suitable for approaching this project, as it aligns with the human-centered focus of bedside nursing practice. Consequently, the initial approach to this project consists of three iterative cycles, each starting with research and ending with testing a protype of a design.

However, during the first cycle, it became clear that as an outsider to the medical field, it was more challenging to gain a comprehensive understanding of the practice in such a short period of time. Insights into the acclaimed problems and user needs were gathered, but they were based solely on initial impressions and a single nurse's perspective. This also ties into possible concerns of HCD approaches that Donald Norman addresses, such as the fixation on individuals and listening to their perceived needs (Norman, 2005).

Activity-Centered Design

Therefore, Norman suggests, in what he calls an 'enhancement' of HCD, that a more activity-centered design focus could generate more universal understanding and alignment with design contexts (Norman, 2013). Thus, it was decided to spend more time getting familiarized with and analyzing the practice to develop any design direction that poses true value for all nurses in practice. This decision led to reconsider the iterative design sprint approach in favor of a more traditional linear approach, also known as the waterfall model, allowing for more extensive research time in three consecutive phases.

Nonetheless, the iterative essence of converging and diverging, inspired by the Double-Diamond Model of Design, was still implemented to uphold the value of HCD in accurately identifying needs from practice (Design Council, 2024). This

> *How can we pretend to accommodate all of these very different, very disparate people? The answer is to focus on activities, not the individual person. I call this activity-centered design.*
>
> *- Norman (2013)*

approach is put into practice by the scheduling of recurring research activities involving nurses, which serve as critical evaluations of the current project progress. These research activities are designed with a dual purpose: to assess existing findings (converging) and to generate new insights (diverging). Ultimately, this approach has shaped the project structure as depicted in Figure 5.

Research through Design

Another primary design methodology applied throughout the project is Research through Design. This methodology focuses on using design activities as a means of research, generating new insights into interactions and practices (Stappers & Giaccardi, 2014).

The practical approach of design activities not only helps refine design concepts but also fosters a deeper understanding of the context in which these solutions will be implemented. It is a particularly valuable approach for exploring desired future perspectives in practice, as it incorporates individuals outside the design domain into the design thinking process. The application of this methodology will be further elaborated in Phase 3 of the project.

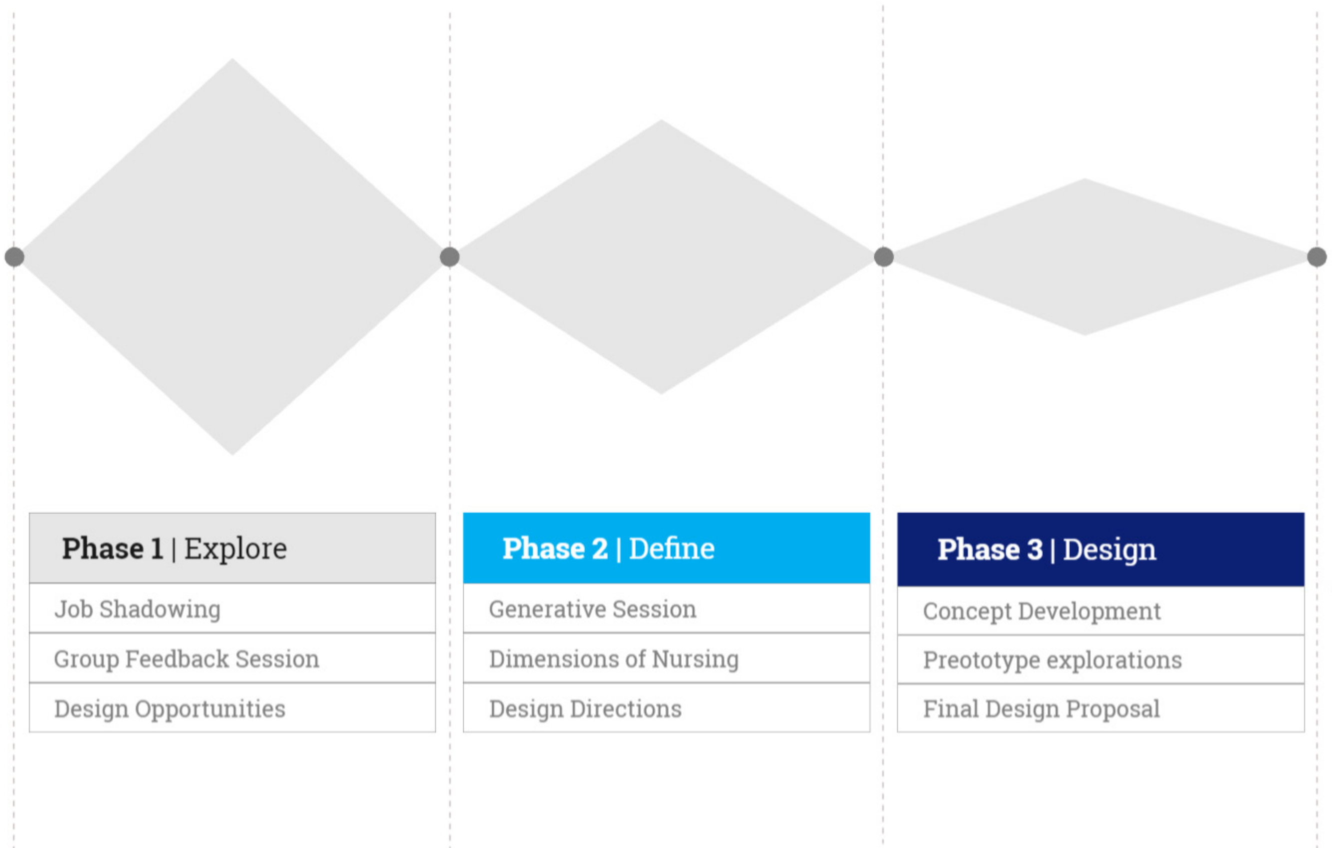


Figure 5: The three different phases of the design approach.

Phase 1 | Discover

Where should one start when designing for the nursing practice? This is probably a common question for designers, engineers, and roboticists outside the medical field. Healthcare practices can seem like distant islands, difficult for outsiders to access due to the closed doors of clinical expertise and regulatory complexity. Therefore, it might be tempting to start developing technological innovations without the costly investment of time and effort in extensively exploring the design context.

However, following the principles of Human-Centered Design, it is essential to learn the what, how, and why of things happening in practice to design solutions that address human needs, capabilities, and behaviors. Renowned American author, professor, and researcher Donald Norman describes it as follows:

> *Human-centered design is a design philosophy. It means starting with a good understanding of people and the needs that the design is intended to meet.*
>
> \- *Norman (2013)*

It is precisely the holistic approach to human needs, in which clinical expertise, empathy, and intui-tive considerations are essential to healthcare. The human insight and emotions involved in care make nursing a spontaneous and dynamic practice, unlike more structured contexts that involve robots at work. This makes immersion in the design context and understanding the people espe-cially important for such nursing practices.

This first phase of the project will discuss the initial exploration within the bedside nursing practice, from the first impressions of context visits to the insights and conclusions drawn from these expe-riences. Group discussions with nurses are used to initiate conversations about common problems, desired changes, and identified needs. The phase concludes with possible design directions for the specific context of the Children's Thorax Center ward at the Erasmus MC Sophia.


Verpleegafdeling
Kinderthoraxcentrum
Laat jij mij ook met een gerust hart spelen?
Alyshia, 6 jaar, heeft 1 long

Chapter 2 |
The people of the beside nursing practice

Bedside nursing is the heart of patient care, where clinical expertise meets compassionate interaction. This chapter will explore the initial research activities undertaken to familiarize ourselves with the bedside nursing practice at the Children's Thorax Center ward at Erasmus MC Sophia in Rotterdam. It will identify the relationships between the various people, artifacts, and locations that comprise the complex network of this practice. The chapter will demonstrate that nursing is not merely a series of structured procedures and tasks but a diverse and spontaneous profession driven by intuition and a motivation to deliver the best care possible for patients. By the end of this chapter, readers will gain a deeper understanding and appreciation of the practice's complexity, gaining foundational knowledge to further develop opportunities for innovation and design.

2.1 Job shadowing nurses

Experiencing the bedside nursing practice firsthand is one of the fastest ways to familiarize yourself with the design context. However, as a researcher with no prior experience or training in the medical field, this can be challenging. Fortunately, there are university medical centers such as the Erasmus MC, which made it possible to arrange job shadowing activities with two different nurses during their working shifts at the Children's Thorax Center ward, as depicted in Figure 6 below.

Figure 6: Children's Thorax Center ward at the Erasmus MC Sophia.

Contextual Inquiry

The job shadowing experience for a non-medical researcher is already eye-opening and valuable on it own, but following a pre-planned research technique or methodology could bring further guidance throughout the activity and capture more valuable insights. One such research technique within qualitative design research is Contextual Inquiry.

> *The cornerstone of contextual inquiry is to collect data in the context of users' work as a partner with users. We talk with users while they are working. We see which aspects of a system support or interfere with work and how that system interacts with the whole work context.*
>
> *– Wixon et al. (1990).*

Originally developed by Whiteside et al. (1998) as a research technique in the field of computer science, it approaches the relationship between the designer and user as an apprentice learning skills from a master in the expertise of use. This so called 'enabling learning' by Beyer & Holtzblatt (1995) is the designer learning from the user through observation and interaction during the practice, not for example through an abstract reflection of the user via an online interview.

Applying this to the context of bedside nursing means that a designer could learn the most from the nurse by participating in bedside nursing practice through real-time observations and discussions. Healthcare practices have the added challenge of dealing with medical jargon and procedures, making it even more useful to have in-practice discussions for clarification. Therefore, this research technique is well suited for the job shadowing activities. However, unlike common contextual inquiry activities, no interview will be conducted after the shadowing is completed. The shadowing of an eight hour working shift is already an extensive time investment for the people involved and time for processing new learnings is necessary. Further insights and findings of the contextual inquiry will be discussed in the group feedback session in the next chapter.

Figure 7: A collage of pictures collected during first shadowing visit.

Shadowing day 1

The first shadowing was held in the first week of the project, during an eight hours day shift at the Children's Thorax Center ward in the Erasmus MC Sophia. The researcher wore a nursing uniform with an employee ID-card and did not partake in medical intervening during the shift, following the conditions set by the Erasmus MC.

The main goal of this research activity is to serve as an introductory experience into the nursing context. For such initial experience it is therefore important to provide the researcher with enough space to take in the full experience of the practice. Only a small notebook was used by the researcher and some pictures were taken as reference and reminders to the experience, see Figure 7. As overburdening the attention with continuous data collection will take away from the involvement in the experience.

The initial experience resulted into great first impressions and insights, that will be further discussed into detail in next sections. The contextual inquiry techniques, such as live questioning and discussions, were effective in quickly getting to know the typicality and reasoning within the practice.

Figure 8: Photo of shadowing visit day 2.

Shadowing day 2

The initial shadowing generated a good general impression of the nursing practice, but it was unclear if the nursing approach experienced with this specific nurse was typical for the bedside practice. Furthermore, the learned insights were sufficient as foundation knowledge, but it was impossible to collect the deeper and detailed knowledge as an first impression. Therefore, a second shadowing activity was organized with a different nurse to gain another nurse's perspective and observe the practice more precisely with established knowledge.

This second shadowing activity was done a few weeks after the first one, as time was needed to process the almost overwhelming amount of initial impressions. The activity was conducted during another eight hour day shift and at the same ward as the initial shadowing. Similarly, the researcher wore a nursing uniform and hospital ID-card. However, this time a note taking template was prepared to allow for structured and focused data gathering, unlike the previously discussed open data gathering approac]. This way, the researcher is able to focus on writing down detailed insights, while keeping track of each nursing activity.

The second shadowing resulted into a more detailed overview of each activity in the beside nursing practice. It brought understanding of new nursing activities, the specific actions and reasoning involved in each nursing activity, and the differences in a nurse's personal motivations and approach. Ultimately, the job shadowing activities provided a great opportunity for a researcher outside the medical field to experience and learn the bedside nursing practice.

2.2 The people involved in the practice

Healthcare practices in hospitals encompass a diverse spectrum of medical personnel who collaborate to provide optimal patient care. This collaborative effort is particularly pronounced at the Children's Thorax Center at Erasmus MC Sophia, where the ward specializes in treating children with conditions related to cardiology, respiratory, and digestive systems. Nurses at this ward interact with a wide spectrum of people, from patients with varied medical conditions, treatments and family support situations, to the interaction with various medical specialists. This section will focus on the people involved in nursing practice, exploring their roles and significance in providing bedside care at this ward.

Who are the patients?

The patients on this ward are children ranging from newborns to 18 years old, with a variety of conditions spanning from the neck to the abdomen. However, the clear majority of patients are newborns who require extensive rehabilitative care following intensive surgeries.

Collaborative care

Hospitalization of a child demands involvement of parents or other family caretakers. Some parents only visit their child once in a while, due to job obligations or other circumstances. In such instances, more of the patient's care is solely conducted by the nurse. However, at the Children's Thorax ward in Erasmus MC, parents, typically mothers, also have the option to actively participate and stay overnight in their child's patient room. These parents play a crucial role as caregivers in the bedside nursing practice.

The role of the pediatrician

The pediatrician is a medical doctor specialized in treating children, possessing trained medical expertise. They are actively involved in the medical treatment, assessment, and planning for patients. Nurses regularly exchange information with pediatricians through the HiX Digital Health Platform and through scheduled meetings known as 'doctor's visits', 'physician office visits', or 'consultation meetings'. During these meetings, nurses share their observations and reports with pediatricians and the ward physician.

A nursing Ecosystem map

Ecosystem maps are a visual data representation technique used in service design to capture all the aspects of a service environment from the user's perspective. Key elements of ecosystem maps include the identification of all players and entities, the representation of their respective relationships with arrows, and the identification of opportunities and pain points within the map (Service Design Tools, 2024; Interaction Design Foundation, 2021).

The concept of ecosystem maps holds significant value in capturing a comprehensive overview of practices, encompassing elements such as players, relationships, and their relative positions within the practice. Consequently, the overview in Figure 9 has been created to illustrate the bedside nursing practice at the Children's Thorax Center ward.

Nurses serve a vital role in the practice, acting as providers of bedside care and mediators of most interactions within the practice. Therefore, pediatric nurses are placed at the center of the map, identifying them as the primary target group for this project. The layers in the map represent the proximity levels of the practice. Most of the nursing occurs bedside in the patient room, where the main players form the core of the practice. Zooming out, the layers encompass the ward and the hospital itself, where nursing activities occur less frequently.

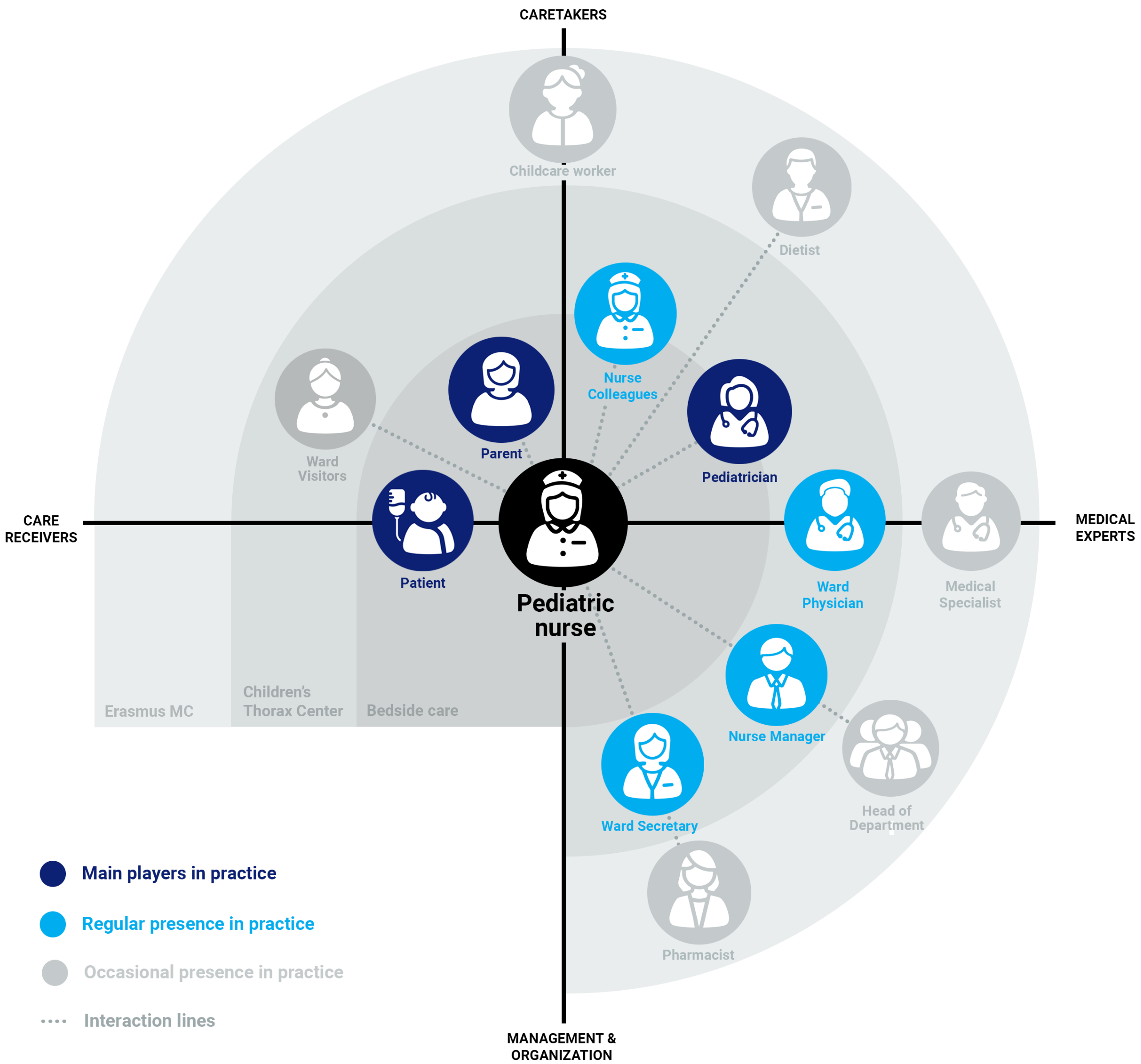


Figure 9: Ecosystem map of the bedside nursing practice at the Children's Thorax Center ward.

2.3 Getting to know the pediatric nurse

Nurses are the focal point in understanding the practice, as discussed in the previous section of the ecosystem map. They are the experts of use, experienced practitioners in performing and engaging with the practice as trained professionals. Questions need to be asked, such as: Who are they? What motivates them? Why do they do the things they do? It are in those answers that a designer can find the necessary understanding for uncovering user needs, which on its turn can lead to opportunities for design directions.

Pediatric specialization

In the specific design context of this project, the Children's Thorax Center ward at Erasmus MC Sophia, all nurses require a nursing specialization as children's nurse. This specialization, also medical known as pediatrics, is necessary as it focuses on nursing on physical, psychological and social levels for children aged 0 to 18 years. Requiring a broad and diverse spectrum of medical diagnosis and intervention to be specific for each child's development phase (Erasmus MC, 2024).

The need for pediatric specialization is also manifested in the capabilities of the patients that influence the way of care. A nurse participant expressed this during the generative session as the following:

> *The difference of nursing children compared to adult care is that adults are patients when they enter the hospital. They can simply communicate and move around on their own, with exceptions if they are really ill. Children are almost never patients as they cannot signal if something is wrong or tell you if something hurts*
>
> *– Nurse participant*

This fundamental difference in patient care is important to acknowledge, as it is indicative of medical specialization and ward specific needs. Pediatric nurses rely more on the vital monitoring, observations and medical insight to determine the wellbeing patients, which in effect asks for more cognitive engagement of the nurses compared to adult care.

Switching between roles

Another striking aspect observed during the job shadowing are the multifaceted roles that a pediatric nurse is able to switch between during a working shift. A pediatric nurse is spontaneous and friendly when greeting the patient, but also professional and coordinated when discussing medical treatment with parents. Showing medical competence in discussions with physicians, while the next second being silly and playful by positively distracting a patient during treatment. Intuitive use of social skills, such as language and demeanor, depending on the situation at hand, as illustrated in Figure 8.

Pediatric nursing is not only the nursing of children, it is also coordinating collaborative care. As mentioned in Section 2.2, "The people involved in the practice," parents can choose to actively participate in taking care of their child and stay overnight in the patient room. During the ward visits, some parents were responsible for feeding the child or even simple medication administration. In such cases, which was commonplace based on the observations and feedback of nurses, pediatric nurses take the role of coordinators. Showing leadership and guidance to parents, by making sure that diet programs and medication plans are followed accordingly.

Meanwhile, pediatric nurses also take the role as a medical expert and a spokesperson. Medical information and the plan for further treatment is generally given during so called 'family physician visits'. In these visits parents are invited to a meeting with physicians and the responsible pediatric nurse to discuss the medical status of the patient and the following best course

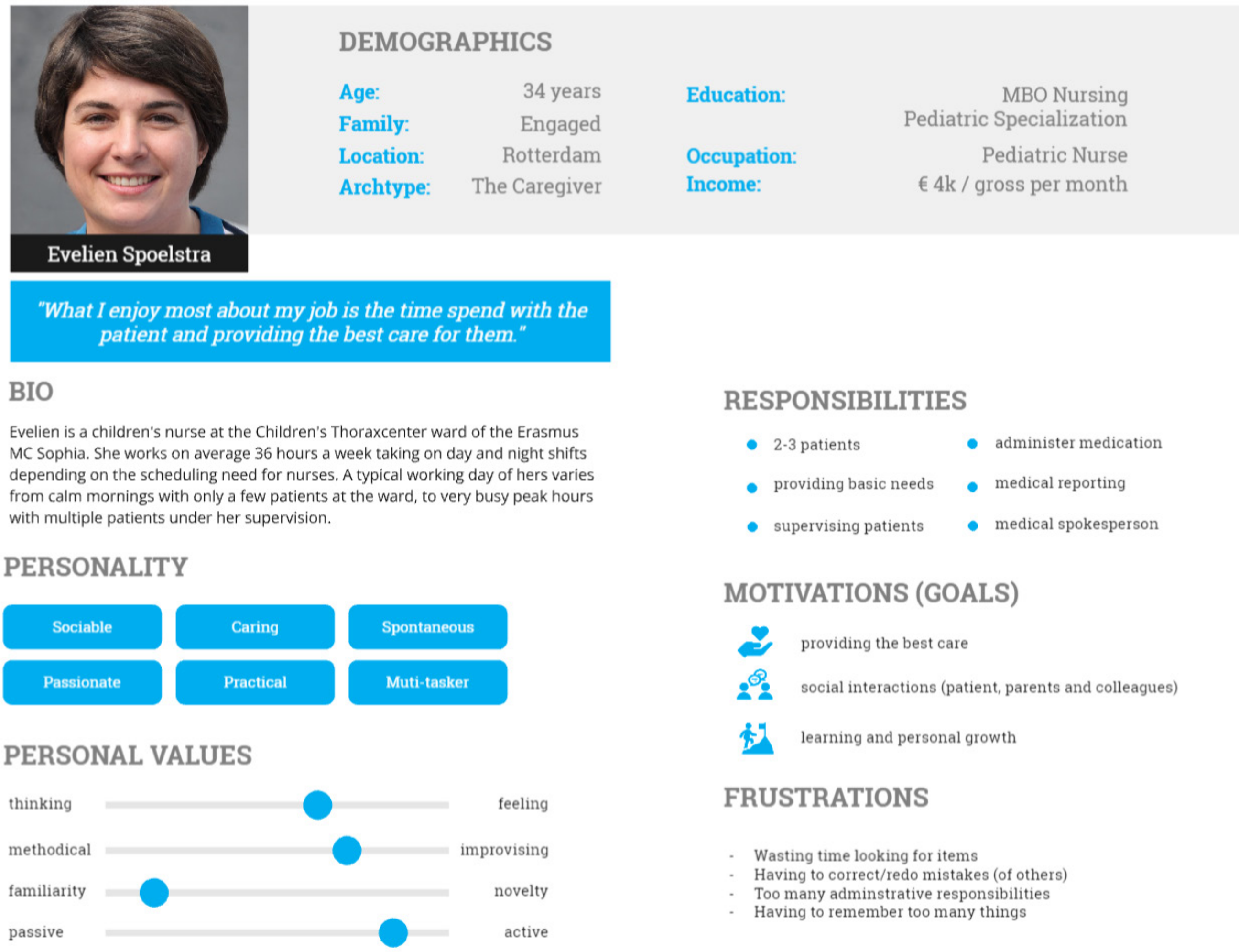


Figure 10: Pediatric nurse persona.

of action. During these meetings the pediatric nurse takes the role as a medical reporter on observations of the patient's wellbeing and progress. They serve as the eyes and ears in the patient room and are tasked to communicate the administration and execution of medical intervention. Also outside of these meetings, being a pediatric nurse demands adjusting the room thermostat by request of visitors to providing answers to doubts about a patients wellbeing by a patient's parent. They serve as the face of the hospital experience by the patients and family caretakers.

Composition of the target group

Statistics of the Dutch Ministry of Health, Welfare and Sport of June 2024, show that 88% of all registered nurses in the Netherlands are female. This also seems the case for the children's nurses at this specific ward, which are predominantly female with a handful of male nurses. The same statistics also show that the biggest age group under registered Dutch nurses are aged 30-40 years, with also big representation for the younger than 30 and 50-60 years age groups (Ministerie van Volksgezondheid, Welzijn en Sport, 2024).

This was also noticeable during the visits to the children's thorax ward, as there seemed a clear difference in technological stance and behavioral routines between younger nurses (aged 20-40 years) and the more experienced nurses (aged 40-60). Note that these conclusions are based on the are approximations based on the research visits to the children's thorax ward. Exact statistics of the specific ward was not found to be published by the Erasmus MC.

Younger nurses seemed to be more open and desiring towards the prospect of new innovative interventions. Whereas, the more experience nurses seemed to prefer existing routines and skeptical towards technology. A difference in behavioral approach, e.g. routines and habits, to nursing activities was also noticed. Younger nurses are relying more on procedures and protocol, using extensive note-taking and using the newer devices intended to modernize the practice. Nurses explained this as 'training behavior', as younger nurses come right from their training into the job, with structured procedures and approaches still fresh in memory. A nurse once said the following during the contextual inquiry:

> *They take time to get used to the real practice. Once they do, they will see how things really work over here and also develop their own way of doing things.*
>
> *– Nurse participant*

Which is probably true, as more experienced nurses seem to have developed their own more efficient and effective way of doing activities in the practice. For example, there are mobile computer trolleys called 'Cows' present at the ward, intended for local access to the EHR for measurement administration and medical reporting, as depicted in Figure 11. During shadowing, an experienced nurse did not use the Cow at all. According to this nurse, they are too much of a hassle to move around due to their size and you waste time searching for an available one.

> *Newer nurses use the Cow as it is part of their training or take extensive notes on a sheet of paper. Then again, if you develop experience, simply remembering stuff becomes the easier and faster way of doing things.*
>
> *– Nurse participant*

It such cases of intuitive thinking for efficiency and effectiveness, that these nurses strive to spend the most quality time in the practice. In the end, becoming better caretakers that make improvised guided decisions though insight and intuition.

Figure 11: The Computer on Wheels (COW) moved around by a nurse.

2.4 Understanding user needs

The contextual inquiry generated a wealth of knowledge about the practice, yet not all of this knowledge is useful for design development. The valuable information lies in the insights, which refer to problems, opinions, unmet expectations, as well as desires and wishes for future changes. These insights contain the critical information needed to identify possible design opportunities while maintaining user desirability. In UX design, the concept of 'user needs' is a foundational approach to identifying the desires, goals, expectations, and preferences of the intended users of a design or service. This approach emphasizes understanding the user holistically, considering both their explicit requirements and implicit motivations. By focusing on user needs, designers can create more effective, intuitive, and satisfying experiences that align closely with what users seek (Interaction Design Foundation, 2016; Barsoux et al., 2022).

The translation process

A list of useful insights was compiled from the knowledge gathered during the contextual inquiry. Each insight was then thoughtfully analyzed and translated, detailing the current state of practice, the desired transformation, and the underlying user need, see Figure 12. This structured approach ensures that the design development process is informed by meaningful and actionable insights, ultimately leading to more user-centric and aligned solutions. It is also important to note that some user needs in this list refer to patient needs rather than needs directly related to nurses. However, these needs emerged during the contextual inquiry, and their inclusion ensures a comprehensive understanding of the broader context in which nurses operate.

Step 1: Contextual Inquiry Insights

The first step in the process is to decide which insights contained useful information for identification as user needs. This is accomplished by thoroughly reviewing the notes from the initial shadowing visit and the activity log of the second visit. Any annotation or piece of information that referred to a problem, opinion, unmet expectation, desire, or wish was added to the list of user need insights. Reoccurring insights are merged into a single representative insight, while insights referring to different specific instances of the practice were kept separate. The goal of compiling this list was to create an initial reference for nurses to later reflect upon. Therefore, it was not a priority to have a complete and detailed selection of all the user needs, as it will be iterated and expanded upon based on nurse feedback. This approach ensured that the initial list was both manageable and relevant, providing a foundation for further refinement and validation through continuous user engagement.

Step 2: Current state in practice

The next step is to determine the current state in practice referred to in each contextual inquiry insight. This serves as a reference to the 'pain points' that are the root causes behind the indicated experiences or observations. These points can vary from significant problems that need to be addressed to minor inconveniences that can be improved.

Step 3: Desired transformations

The desired transformations are representative of the changes in practice indicated by the given insights. They are essential to the description of the user needs, as they provide perspective on the direction and goals of the envisioned desired practice by nurses.

Step 4: Implicit human needs

Finally, underlying implicit human needs can provide added descriptive and reflective value by connecting practice changes to human feelings. Therefore, the 'Nonviolent Communication (NVC) Needs List' by Sociocracy For All was utilized in the translation process of the list (Wilder, 2019). The NVC Needs List was selected for this analysis as it offers a suitable selection of needs based on the nine universal human needs identified by renowned economist Manfred Max-Neef.

Discussing the results

The translation process served as an effective tool to identify a total of 23 user needs from the insights gathered during two job shadowing activities. It has revealed a clear desire among nurses for efficiency and clarity in their daily practice. The cause of these desired needs is the disruptions in their work, which nurses often identify as tasks perceived as ineffective and detracting from direct patient care. One such example, repeatedly mentioned by the nurses, is the burden of manually entering data into the Digital Health System called Hix. Nurses emphasized the challenge of remembering or writing down measurements or other bedside information to later input into a desktop computer. Their desire is to have data entered automatically at the point of care, highlighting the need for efficiency and effectiveness.

Furthermore, the lack of cohesive vision and communication within healthcare settings can exacerbate these challenges, leading to uncertainty and increasing the likelihood of mistakes among nursing staff. For instance, nurses illustrated the absence of real-time patient activity monitoring except for vital monitoring alarms, which hampers their ability to have a comprehensive view of patient status remotely.

Figure 12 shows a few examples of how this translation process was conducted.

Contextual Inquiry Insights	Current State *[pain points]*	Desired Transformations *[goals]*	Implicit Human Needs *[unmet needs]*
Nurses have to shout for "practical" assistance of colleagues, such as questions or an extra pair of hands to hold something. They don't use the Telecare alarm system, because that is only for medical emergencies.	Nurses have to shout from a distance or look for a (specific) colleague when in need of non-medical assistance, which is inconvenient and takes valuable time.	Nurses should have better means to communicate with each other from a distance.	Communication, Support and Efficiency
	Nurses have request assistance when they are short-handed during a nursing task.	There should be better tools that serve as an extra pair of hands during the treatment of patients (e.g. holding things or pass tools).	Autonomy, Efficiency and Control
When exchanging shifts nurses have a short briefing for exchanging information. However, during a shift other uncertainties about task completion and measurement data might arise.	Nurses have uncertainties about tasks and measurements their predecessor has done after they exchanged shifts.	There should be tools to gain better insight into completed measurements and tasks (e.g. from colleagues from the shift before).	Clarity, Safety and Confirmation
Nurses constantly receive notifications (alarms) from the Telecare system, but most of these notifications aren't urgent. Yet they still need to drop everything they are doing to check into the other room, to see if the notification is caused by something important/critical.	Nurses have to physically go to a patient room to see what the patient is doing that could cause the notification, which takes time and disrupts the nursing practice.	Nurses should remotely (without being present in the room) be able to better see what the patient is doing.	Clarity, Understanding and Confirmation
	Nurses have to physically go to a patient room to check the vital signs and pump-status, which takes time and disrupts the nursing practice.	Nurses should remotely (without being present in the room) have better access to vital signs and pumps (e.g. heartrate or IV-pump).	Clarity, Understanding and Confirmation
•••	•••	•••	•••

Figure 12: Partial representation of the evaluation table used to reflect on design opportunities.

Chapter 3 |
The role of technology in the practice

Technology has revolutionized the healthcare landscape throughout its history, improving the quality, efficiency, and delivery of patient care. This evolution is equally evident in bedside nursing practice, where advancements in electronic health records (EHRs), mobile monitoring technologies, and medical smartphones have transformed traditional nursing activities. However, as current technological interventions in use demonstrate, proper integration into nursing practice is essential to achieve improvements that outweigh the associated costs. This is especially critical in the current context of mounting challenges, such as nurse shortages and an ever-increasing demand for high-quality care. This chapter will focus on the role of technology in bedside nursing practice. It will explore technological developments in the healthcare sector, analyze the technological interventions currently in use, and conclude with insights for designing future technologies.

3.1 Technological developments in healthcare

The awareness of current technological advancements in healthcare serves not only to stimulate innovative design directions but also as a crucial means to avoid reinventing existing solutions. With the recent surge of interest in Artificial Intelligence (AI) across society and scientific domains, it is unsurprising that extensive efforts are already underway to integrate AI into healthcare. However, AI is not the sole prominent development on the horizon; there are also significant advancements in Robotics, smart wearables, Internet of Things (IoT), and Extended Realities (XR). This section will delve deeper into these ongoing technology developments and initiatives, aiming to gain a comprehensive understanding of the evolving healthcare landscape.

Artificial intelligence

The benefits of artificial intelligence (AI) for healthcare have been recognized and studied for decades, as it promises to enhance detection and diagnosis capabilities beyond human limitations. Advancements in deep learning, an advanced subset of machine learning, are predominantly directed towards enhancing medical image analysis processes. This progression within radiology, known as Radiomics, facilitates more precise diagnosis of cancerous tumors by medical professionals, see Figure 13 (Fakoor et al., 2013; Vial et al., 2018).

Conversational AI, commonly known as Chatbots, encompasses machine learning algorithms, specifically Natural Language Processing (NLP), engineered to interpret human language. This subfield of AI has already found widespread integration as automated online customer support systems. Recent advancements in this field of AI aim to extend the capabilities of automated user interactions, including scheduling appointments, monitoring patients, and identifying symptoms through conversational interfaces (Savvycom, 2024).

Expert systems are another commonly utilized

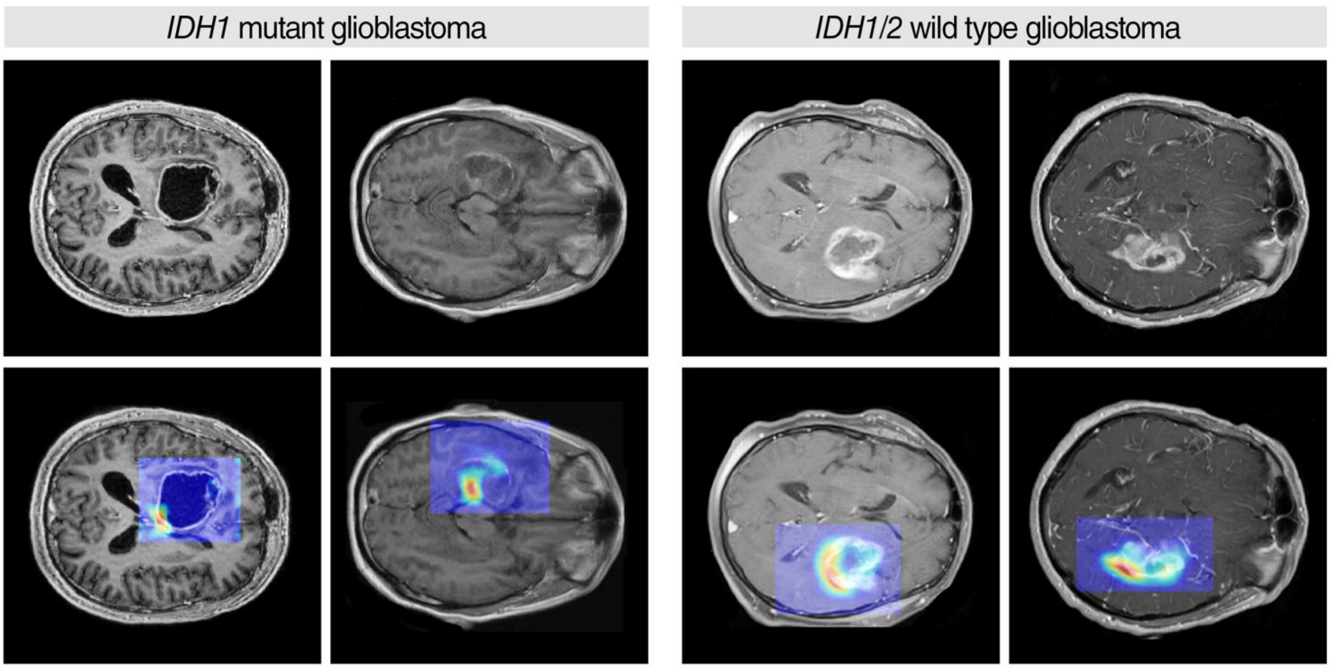


Figure 13: Application of deep learning for cancer recognition in the blue areas (Bi et.al, 2019).

subset of machine learning for managing clinical data in Electronic Health Records (EHRs). Within expert systems, case-based reasoning (CBR) systems can automate diagnosis by identifying similarities in datasets, while rule-based reasoning (RBR) systems facilitate automated decision-making for risk prediction (Seto, 2012; Mustafa, 2023).

These are a few examples of AI implementations in healthcare practice; however, many others are not covered in this thesis as they fall outside the project scope. The overall takeaway from AI developments in healthcare is the enhancement of medical detection capabilities, risk prediction, and automated medical assistance (Davenport & Kalakota, 2019).

Robotics

Artificial intelligence is also utilized in robotics, a branch of mechatronics that focuses on computer-operated machines, which are predominantly autonomous in their physical functioning. Robotic development have mostly found their way in the healthcare practice through automation of physical tasks in logistics, storage and patient handling. The potential benefits of these advancements have spurred technology companies to develop specialized robotics tailored for hospital environments.

One such company is Blue Ocean Robotics, recognized for its development of robots designed for ultraviolet-light disinfection (UVD) and patient transfer and rehabilitation (PTR). The UVD robots saw a significant surge in demand and popularity during the COVID-19 pandemic due to urgent requirements for hospital disinfection. Their PTR robots, on the other hand, focus more on nursing-related tasks such as patient lifting and repositioning, which are routine activities for healthcare workers (see Figure 14a). These robotic cranes contribute to enhanced safety during rehabilitation exercises and patient movement (PTR Robotics, n.d.; Blue Ocean Robotics, n.d.).

Erasmus MC has also implemented robotics in recent years, including Robot Temi, an autonomous AI assistant with an interactive display for versatile applications (Temi, 2023; Welbo, 2024). Currently, research and testing trials are underway to evaluate Temi's potential effectiveness in assisting visitors and patients at the hospital, see Figure 14b.

Other initiatives involving robotics at Erasmus MC are implemented at the pharmacy department. The PillPick Robot, a robotic installation, is used to automate the distribution and packaging processes of medication (Drexhage, 2020; Erasmus MC, 2020). This robot enhances the efficiency of the distribution process by operating continuously and relieves pharmacy workers from repetitive tasks (Figure 14c). A more recent addition, called Robbie, has also been undergoing trials within the pharmacy department. This delivery robot is tasked with the autonomous transportation of medical supplies and medication throughout the hospital. As detailed information about the trial has not yet been published by Erasmus MC, the effectiveness of this robot remains under evaluation.

Finally, there are clinical applications of robotics, such as the Da Vinci Robot, as seen in Figure 14d. Implemented in 2010 at the Erasmus MC, this robot aims to enhance surgical precision for more high-risk surgeries, like bladder removals (Erasmus MC, 2020; Intuitive, 2024). It features four arms suspended from a console and is operated remotely by the surgeon, making it debatable on whether it should be classified more as a telemetric device rather than as a robot.

In conclusion, robotics play crucial roles in automating healthcare and enhancing clinical capabilities through machine precision. Ongoing developments in this field suggest that robotics will increasingly serve diverse purposes in addressing future staff shortages, thereby improving healthcare efficiency and alleviating workloads for human personnel.

Figure 14: a) PTR Robot (PTR Robotics, n.d.); b) Temi Robot (Notermans, 2023.);
c) PillPick Robot (Heembouw, 2024); d) Da Vinci robot (Erasmus MC, 2020b).

3.2 Artificial analysis of the practice

The nursing practice involves a wide variety of objects, from ballpoint pens to advanced vital monitoring systems. These so-called 'artifacts'—man-made objects and tools—serve varied roles through their materiality and usage within nursing practice. Some are less prevalent, functioning merely as tools, while others act more autonomously as players, much like the people involved in the practice. Understanding the roles and positioning of artifacts in nursing practice is therefore essential for creating a comprehensive understanding of bedside nursing. This section will focus on this material side of the practice by identifying, analyzing, and mapping these artifacts in a variation of an ecosystem map.

Nursing gear

Similar to other professionals, nurses possess a specialized toolkit of instruments and equipment essential for executing their nursing duties. Foremost among these is the nursing uniform, which serves not only a symbolic and recognizable function within the profession, but also a critical medical role. The uniform functions as a barrier, offering protection against infections for both patients and nurses within a safe and hygienic clinical environment. Similarly, nurses are required to change their shoes before commencing their shifts. They bring their own work shoes, typically opting for comfortable options, as their duties necessitate prolonged periods of walking and standing. To complete their outfit, nurses are also required to visibly carry their ID cards clipped to a pocket, ensuring they are identifiable as medical hospital personnel at all times during their duty, as illustrated by Figure 15.

Moreover, nurses routinely carry essential general office tools, such as ballpoint pens or colored gel pens, along with a piece of paper. These tools are indispensable for promptly documenting information. The piece of paper serves as a personalized note sheet, tailored to each nurse's specific needs. It is utilized for recording reminders, measurements, and critical medical observations concerning a patient's health status. Additionally, it functions as a reference sheet containing pre-shift notes on patient information, aiding as reference and preventing mistakes.
Lastly, nurses also carry essential medical tools on their person. These tools include medical scissors, clamps, and tape, which are indispensable for rapid interventions such as opening medication packaging, adjusting tube lengths, and applying bandages and sensors to patients. These instruments enable nurses to perform swift and versatile nursing interventions for spontaneous occurring problems.

The primary connected device carried by nurses is typically a medical smartphone, such as the Ascom Myco 3 or 4 used in this ward, representing an advancement from traditional hospital pagers. These medical smartphones serve as mobile output devices within a 'Telecare Notification System', integrating connected Vital Monitoring Systems, Enteral Feeding Pumps, IV-Pumps, and Bedside Emergency Button Modules. Nurses receive notifications through alarm sounds accompanied by visual pop-ups that provide detailed information about the nature of the notification directly on their medical smartphones.

Furthermore, the smartphone is equipped with dedicated apps such as Zenya for accessing medical information databases, encompassing protocols and medication descriptions. However, nurses consulted during this project reported little use of functionalities beyond the notification system. They highlighted that frequent interactions with the smartphone could detract from bedside care and might be perceived as inappropriate in the presence of patients and their families.

Figure 15: Overview of the nursing gear carried by the nurse.

The artifacts in the practice

Beyond the nursing gear, there are numerous other artifacts integral to bedside nursing practice in hospitals. These artifacts play essential roles, ranging from tools with minor appearances to critical interventions that significantly influence the overall practice. To gain a comprehensive understanding of this array of artifacts, an ecosystem map has been created, as illustrated in Figure 16. In this map, the traditional players are replaced by artifacts, and the relationships between them, visualized by lines, represent direct channels of communication established among these artifacts. A dashed line connects a piece of paper to virtual space inputs, such as the Computer on Wheels (COW), indicating an indirect connection between them. Unlike the ecosystem discussed in Chapter 2.2, "The People Involved in the Practice," the layers in this map represent the positioning of artifacts relative to the nurse, with nursing gear that is always worn by the nurse placed at the center.

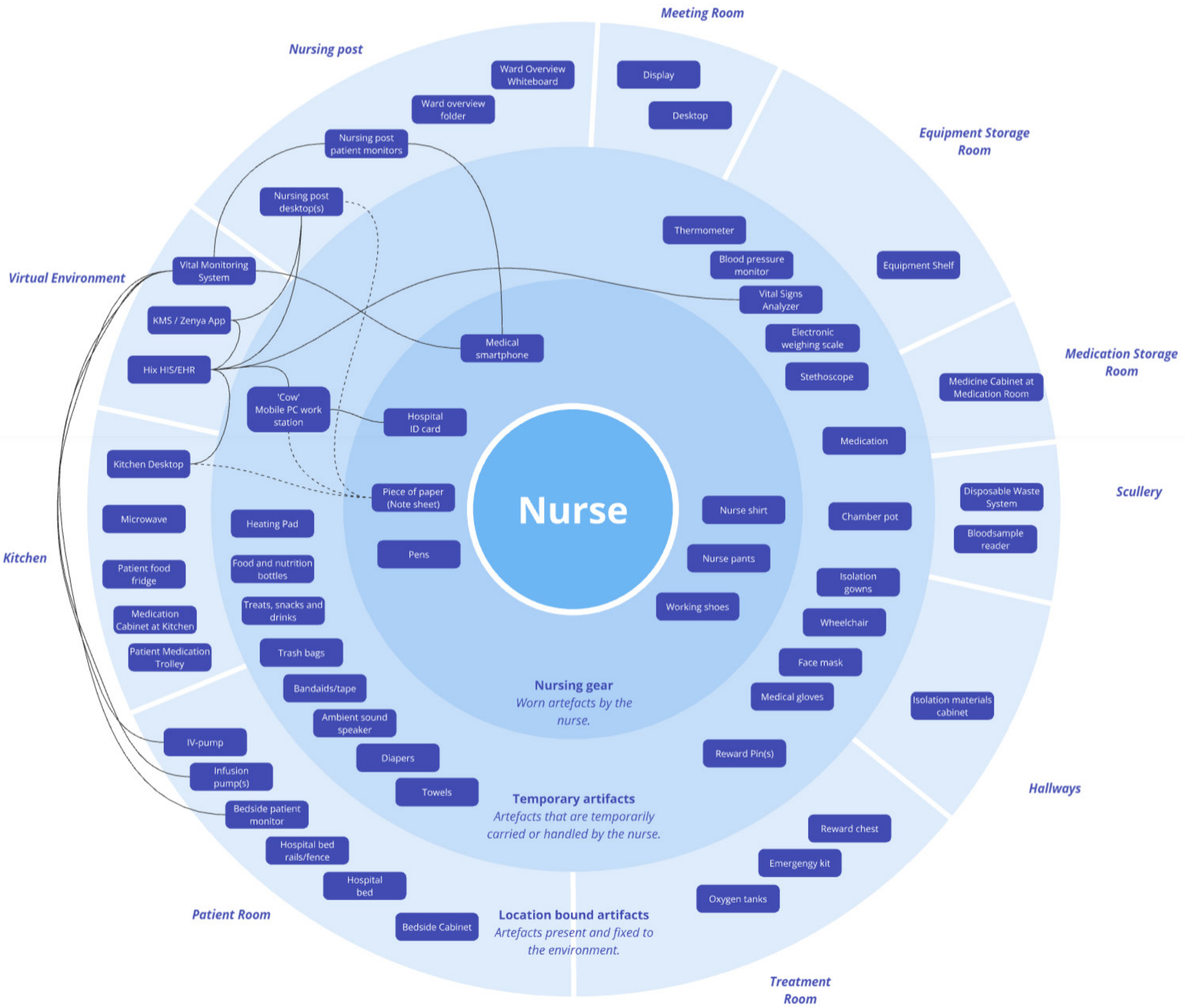


Figure 16: Overview of all the artifacts involved in the practice.

3.3 Learning from current interventions in practice

Throughout the history of nursing, numerous technological designs have been developed. As discussed in the preceding section, medical smartphones have empowered nurses with the ability to monitor patients' vital signs remotely and access medical information. However, each technological artifact presents a spectrum of advantages and disadvantages that are carefully weighed by nurses and hospital management during various stages—from initial development by healthcare suppliers, to allocation by hospital management to specific wards, and ultimately, to the real-time decision-making process of nurses during practice. This section aims to examine and learn from these critical moments of consideration and practical usage in the current practice of bedside nursing.

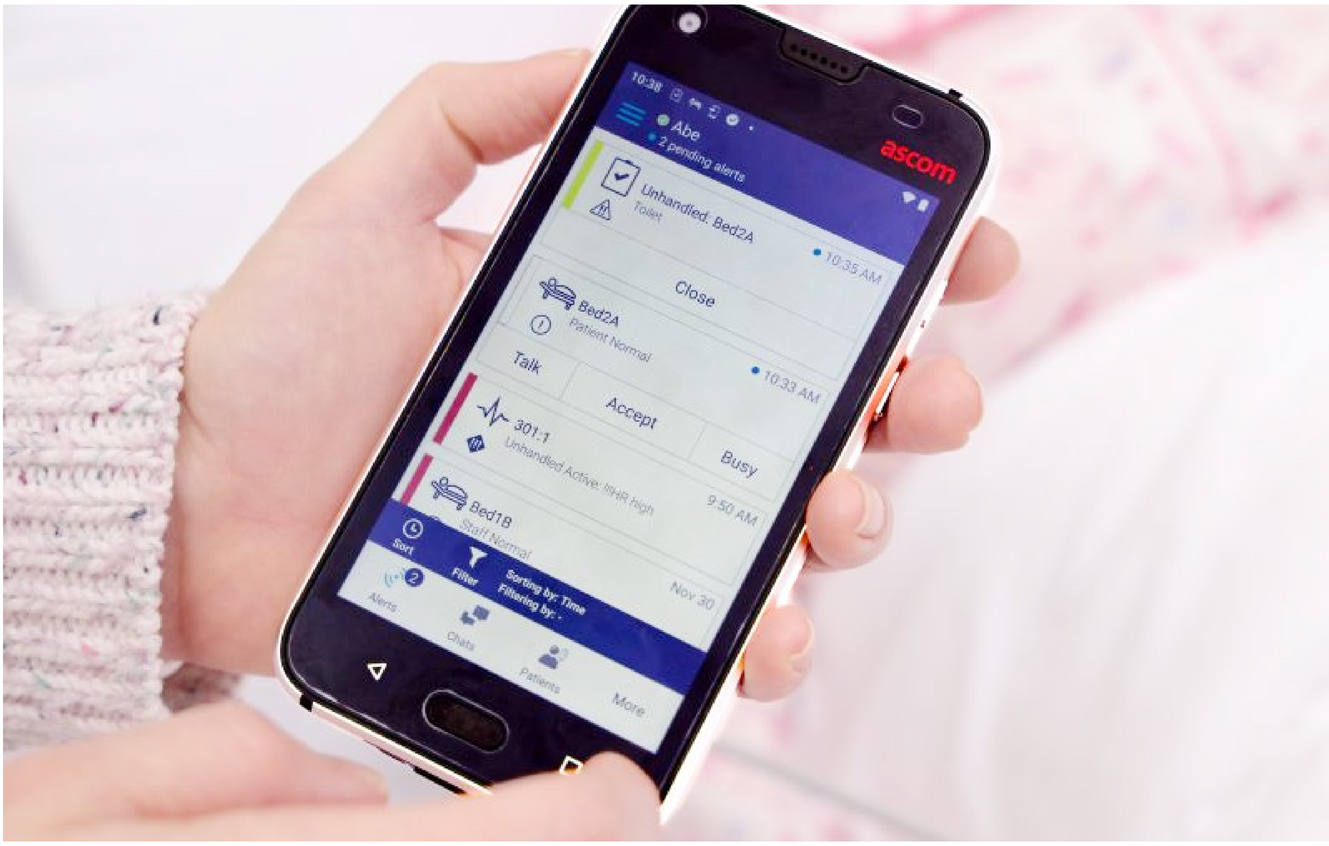


Figure 17: The Myco 3 medical smartphone (Ascom Americas, 2023).

Medical smartphone

As previously mentioned, nurses have indicated limited utilization of the full capabilities offered by medical smartphones (Figure 17). They attribute this to the potential distraction from bedside care and the perceived inappropriateness of extensive smartphone interactions in the presence of patients and others. These considerations are largely influenced by the interactive design of such smartphones. Nurses are inherently pragmatic and must seamlessly transition between various roles, as outlined in '2.3 Getting to Know the Children's Nurse'. They maintain a steadfast focus on their operational duties, continually assessing current actions, reflecting on their implications, and strategizing for subsequent tasks. Thinking of where to exactly find the information they need and navigating to the correct tab in an app is too much of a disruption in such steadfast focus.

Additionally, nurses bear a significant social and ethical responsibility in their practice. Human engagement and compassionate care are fundamental components in fostering trust in healthcare. This responsibility is especially evident in their interactions with children, as parents frequently experience feelings of helplessness and vulnerability due to their child's serious health conditions. Consequently, nurses hold the belief that prolonged interaction with a smartphone, beyond brief checks for notification alarms, may detract from crucial social engagement. They perceive such distraction as potentially jeopardizing the trust established with patients and parents, which is vital for effective caregiving and maintaining a supportive healthcare environment.

The 'COW' (Computer On Wheels)

At the Children's Thorax Center ward, nurses are also equipped with several 'Computer on Wheels' (COWs), mobile computer platforms on wheels, as depicted in Figure 18. These devices are utilized by a limited number of nurses, primarily due to similar concerns regarding their impact on social engagement in patient care. However, a significant distinction between the COW and the medical smartphone lies in functionality and size. The COW facilitates direct access to the Electronic Health Record via the Hix Platform, allowing nurses to enter medical values and generate reports efficiently. Therefore, allowing nurses to conduct their administrative tasks right after reading patient values and administering medication in patient rooms. Despite these advantages, the majority of nurses opt not to utilize a COW in their bedside practice. They perceive the COW as impractical due to its cumbersome size and weight, making it difficult to maneuver. Additionally, nurses often face challenges in locating the device in other rooms and encounter delays associated with logging in and accessing comprehensive data within the system.

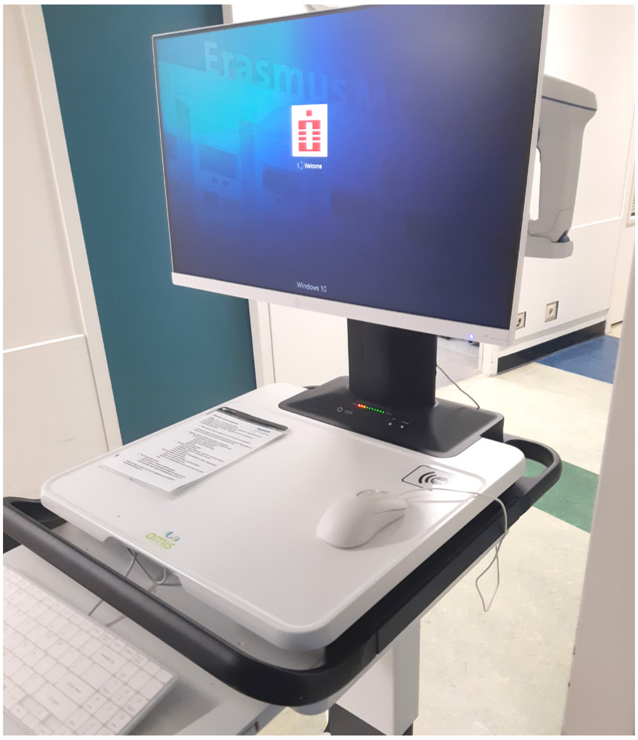


Figure 18: An image of the COW used at the Children's Thorax Center.

Vital Signs Analyzer

Recently, the nurses at the ward received a new Vital Signs Analyzer, a device capable of measuring a patient's temperature, heart rate, and blood pressure in a single unit, as seen Figure 19. Moreover, it offers the functionality to transfer these measurements directly to the Hix Electronic Health Record (EHR), aligning with one of the primary transformations identified by nurses in the user needs analysis. Despite these promising advantages, the nurses participating in this research expressed a preference for older alternatives, citing dissatisfaction with the new device.

The primary cause of this dissatisfaction is the inefficiency and difficulty associated with using the device and making necessary adjustments. Although the device is more advanced and comprehensive, it suffers from slow software speed and cumbersome navigation. During the shadowing, one nurse demonstrated that the device takes an excessive amount of time to start and be properly set up. The process involves scanning an ID card, waiting for the profile to load, selecting the correct patient, and opening the appropriate reading to perform, among other steps. In comparison, older alternatives, such as a simple blood pressure monitor that requires only placing the cuff on the patient's arm and pressing a button to start the reading, are much faster and simpler. Additionally, there are significant inconveniences that arise when errors occur in the data transfer process. Nurses reported that occasionally they inadvertently transfer an incorrect reading or assign data to the wrong patient file in the Electronic Health Record (EHR). Rectifying these mistakes presents considerable challenges, as nurses must navigate a cumbersome process that involves seeking assistance from the hospital's IT desk to correct these data inputs.

In conclusion, insights from current interventions underscore that nurses maintain a pragmatic focus during practice and play a pivotal role in delivering both medical treatment and emotional support. It is evident that technological interventions must not detract from the nurse's primary responsibilities or diminish crucial social engagement. Therefore, interventions should be simple to handle and operate, offering easy control and adaptability to accommodate an efficient workflow.

Figure 19: A Vital Signs Analyzer like the one used at the Children's Thorax Center (Seca, n.d.).

Chapter 4 | Exploring design opportunities

With an understanding of both the people involved and the technological landscape within our practice, the subsequent step is to synergistically integrate these elements to generate design opportunities. The primary objective of this process is to pinpoint design opportunities that not only cater to user needs but also effectively harness technological advancements. However, this juncture marks a pivotal moment where wrong assumptions could potentially lead to a disconnect with the nurses in practice. Hence, realignment becomes essential, which is done by organizing a group feedback session with the nurses at the Children's Thorax Center. This process culminates in a refined inventory of practice improvements, which will undergo rigorous evaluation through reflective analysis of design and technology. This chapter will explore the pivotal process of assessing design opportunities and establishing the future direction of the project.

4.1 Group feedback session

The list of user needs serves as a good overview of possible starting points for design opportunities. However, they are selected by the researcher and extracted from the researcher's perspective during the shadowing activities. The transformations discussed in the previous chapter should be desired by the user, not determined by a research or designer. Therefore, a group feedback session was organized at the nursing post at the Children's Thorax Center ward, see Figure 20. The goal of this feedback session is to engage end users directly at the beginning of the design process, ensuring their genuine needs and preferences are accurately captured. By adopting this participatory approach, the gap between researcher assumptions and user realities can be bridged. Fostering designs that are truly user-centered and more likely to be embraced in practice.

Activity setup

The total duration of the activity was set for approximately 30 minutes. The first 15 minutes were allocated for completing a feedback form, followed by a 15-minute group discussion. The activity was scheduled during the change of shifts, as the nurse contact indicated this would be an opportune moment for a larger group of nurses to participate. Nurses working at the ward were informed in advance about the feedback session. However, a spontaneous and informal approach was recommended by the nurse contact, as it was believed this could encourage more voluntary participation. This strategy proved effective, as a substantial number of 14 pediatric nurses and 1 ward manager willingly participated. The location of

Figure 20: The group feedback session in the nursing post of Children's Thorax Center ward.

the activity, the nursing post, also contributed to the high turnout, as it serves as an informal gathering place for nurses to chat and enjoy some coffee and cake.

The activity was deliberately structured to have participants first fill in their own feedback forms individually, followed by a group discussion of their ratings. This approach ensured that participants were exposed to differing opinions and prompted to articulate and reason their choices, leading to valuable discussions.

Likert scale

A 5-point Likert scale was utilized to assess the 'Relevance' of each desired transformation, ranging from "not relevant at all" to "very relevant", see Figure 21. This approach encourages participants to consider the presented options with nuance, aiding in the decision-making process regarding which direction to pursue (Soegaard, 2024). The term 'Preference' was deliberately avoided in the scaling, as it might suggest whether participants wanted the transformations to occur. Given that the transformations were already identified as 'desired,' this could bias participants towards rating all transformations highly. Instead, using the term 'Relevance' prompted participants to think critically about which transformations were genuinely worth focusing on. This distinction was also emphasized in the verbal introduction of the activity, framing the rating as a valuation system where participants determined the relative importance of each transformation.

Assigning 'favorites'

In preparation for this activity, a credit system was initially considered, where participants would be allocated a fixed amount to spend on each transformation. However, it was deemed too complex for quick comprehension given the short duration of the activity and the size of the group. Consequently, a simplified version was implemented using stickers to indicate preferred transformations. Each participant was given three stickers and asked to place them in front of the transformations they deemed most important to address. This method encouraged participants to compare the transformations and make executive decisions, while also serving as a useful reference to stimulate group discussion and compare the various personal perspectives of the nurses.

Expanding the list of needs

The participants were also provided with space on the back of the form to add and rate their own suggestions for desired transformations. The majority of these suggestions were related to existing transformations already listed in the user needs. These corresponding suggestions were accordingly merged with the existing needs to maintain a comprehensive, yet compact list. Furthermore, added suggestions outside of the scope of the project, e.g. that emphasis on logistical or managerial issues, are for the aforementioned reasons left out. Suggestions that add new diversity to the selection were incorporated separately into a updated list in the next section.

Group discussion

After the completion of individual form submissions by the nurses, a 15-minute group discussion ensued to reflect and expand upon their responses and their underlying reasoning. During this discussion, the nurses expressed a consensus that there was not a pressing demand for additional interventions aimed at calming patients or facilitating patient-to-patient interaction. This sentiment was largely attributed to the patient demographic, as the majority are newborns who are not yet socially responsive beyond their need for interaction with nurses in a maternal role.

Moreover, the ward already boasts an extensive array of interventions, including toys, puzzles, and board games, catering comprehensively to the needs for play. Additionally, older patients benefit from amenities such as televisions in their rooms, alongside personal entertainment items like books and game consoles that they frequently bring with them.

Subsequently, the discussion was directed by the researcher towards technological interventions employed in the current practice. The earlier mentioned Computer on Wheels (COW) was a heavily contested point of discussion. The majority of participating nurses expressed strong opinions against the use of the COW, opposed by a minority defended its utility, highlighting its regular usage.

Many of these discussion points have already been integrated into the technological analysis, detailed in Chapter 3.3, “Learning from Current Interventions in Practice.”

Ultimately, the discussion pivoted towards the identified needs and desired changes in practice as perceived by the group. It was evident from the consensus among the nurses that the most critical areas requiring improvement are communication among nurses and the administrative process of inputting medical data into the Electronic Health Record HiX.

The nurses highlighted that tasks such as seeking assistance and locating nursing colleagues for routine duties pose significant inconveniences during their shifts. Moreover, administrative responsibilities, particularly the entry of data into the system, were unanimously regarded as the most disruptive and burdensome tasks. Collectively, the nurses expressed a shared desire to allocate more time to direct nursing care rather than spending a substantial portion of their shifts on administrative duties.

In summary, the group feedback session provided valuable responses and insights. The nurses demonstrated openness in sharing their opinions and providing examples to support their stance on various transformations. Initial evaluations of the practice analysis appeared to be largely aligned with the nurses’ perspectives, although some adjustments were identified, particularly concerning transformations related to patient-patient and patient-nurse interactions.

Sticker	Gewenste veranderingen	Relevantie-schaal				
	Overzicht hebben	Helemaal niet relevant				Zeer relevant
	Verpleegkundigen moeten op afstand (zonder in de patiëntenkamer aanwezig te zijn) beter zicht hebben op wat de patiënt doet.	1	2	3	4	5
	Verpleegkundigen moeten op afstand (zonder in de patiëntenkamer aanwezig te zijn) beter zicht hebben op patiëntwaardes (bijv. grafiek hartritme/zuurstofgehalte).	1	2	3	4	5
	Ondersteuning					
	Verpleegkundigen moeten betere middelen krijgen om met elkaar op afstand te communiceren.	1	2	3	4	5
	Er moeten betere hulpmiddelen komen die als een extra paar handen functioneren tijdens het behandelen van patiënten (bijv. dingen vasthouden of aangeven).	1	2	3	4	5
	Het zou fijn zijn als hulpmiddelen (bijv. instrumenten-/verzorgingswagens) automatisch naar de verpleegkundige toe komen.	1	2	3	4	5
	Zoeken naar hulpmiddelen					
	Het zoekproces van medicatie in de steriele kast moet makkelijker gemaakt worden.	1	2	3	4	5
	Apparaten/hulpmiddelen moeten makkelijker gevonden worden wanneer ze nodig zijn.	1	2	3	4	5
	Isolatiekamers					
	Het moet makkelijker worden om metingen en andere gegevens in de isolatie kamer ter plekke in te voeren in het systeem.	1	2	3	4	5
	Verpleegkundigen moeten op afstand (zonder de isolatiekamer te betreden) beter zicht krijgen op patiënten in isolatiekamers.	1	2	3	4	5
	Patiënten in isolatie moeten meer mogelijkheden krijgen om interacties te hebben (bijv. spelen met andere patiënten) op de afdeling.	1	2	3	4	5
	Ouders te woord staan					
	Ouders zouden meer begeleiding moeten krijgen zonder dat verpleegkundigen dit hoeven te doen.	1	2	3	4	5
	Metingen en handelingen vastleggen					
	Metingen zouden meer automatisch van meetapparatuur naar de database/het patiëntendossier verwerkt moeten worden (minder handmatig invoer voor verpleegkundigen).	1	2	3	4	5
	Er moeten betere hulpmiddelen komen om geheugensteuntjes (bijv. meetwaardes) te bewaren (i.p.v. de nu gebruikte notie blaadjes).	1	2	3	4	5
	Er moeten hulpmiddelen komen om beter inzicht van voltooide metingen en handelingen te krijgen (bijv. van collega’s de shift ervoor).	1	2	3	4	5
	Er moet een (virtuele) assistent komen die (nieuwe) verpleegkundige ondersteunt hoe handelingen uit te voeren.	1	2	3	4	5
	Ouder-kindrelatie					
	Er moeten (betere) manieren komen voor ouders om met de patiënt interactie te hebben wanneer ze niet op bezoek zijn (bijvoorbeeld vanuit huis).	1	2	3	4	5
	Patiëntervaring					
	Patiëntenkamers moeten levendiger en interactiever worden voor de ervaring van de patiënt.	1	2	3	4	5
	Er moeten (betere) hulpmiddelen komen om patiënten af te leiden tijdens behandelingen.	1	2	3	4	5
	Er moeten (betere) hulpmiddelen in de patiëntenkamers komen om patiënten tot rust te brengen.	1	2	3	4	5
	Er moeten (betere) hulpmiddelen komen die patiënten meer verplaatsingsvrijheid bieden (bijv. infuus-loop standaard).	1	2	3	4	5

Figure 21: Feedback form used for the group feedback session.

4.2 Analyzing feedback session results

The feedback forms from the group feedback session provided personal relevance ratings from each participating nurse. It is now essential to consider how to process and interpret these results effectively to maximize their value. Given the subjective nature of the relevance ratings and the small sample size of nurse participants, these ratings cannot be treated as objective quantitative data suitable for statistical conclusions. However, the collected data is valuable for comparative analysis, offering insights into the priority landscape of the identified transformations. Consequently, the results in this section will be processed through a qualitative comparative analysis to elucidate the relative importance of various proposed changes.

Data processing

The responses from the feedback forms were compiled into a Microsoft Excel document. For the Likert-scale ratings, the average value was calculated and color-coded to provide a clear overview of the differences in ratings. However, the average value can be misleading when comparing datasets with extreme values to those with only average ratings. To address this, a standard deviation value was also included and color-coded to account for the variability in the ratings.

The votes for 'favorites' were collected, with each nurse assigning a sticker to their top three most important transformations. Unfortunately, some participants either forgot to fill in their favorites or placed stickers ambiguously between transformations, indicating a preference for both. These issues were not identified by the researcher during the session, rendering those responses unusable for further processing.

It is important to highlight that the transformations were categorized under specific headings, which adds depth to the practice analysis by revealing correlations between location-specific transformations and general desires regarding the practice. For instance, the categories of 'Support' and 'Isolation Rooms' received high ratings and preferences. However, these high ratings were often driven by a single specific transformation within each category, while other transformations in the same categories scored among the lowest in the dataset.

Feedback results

The group feedback session provided valuable insights into the relevance and preferences of nurses regarding various aspects of their practice. The results emphasize the importance of remote accessibility and communication, particularly in situations where nurses are alone in isolation rooms, as seen in Figure 22. There was a clear preference among nurses for reducing registration tasks, indicating a strong desire for less manual reporting and reduced input requirements for measurements.

The valid votes for 'favorites' were tallied, revealing a clear majority favoring transformations related to reporting measurements and actions, aligning with the discussions held during the group session.

While the quantitative approach to evaluating transformations provides a clear overview of identified needs, further qualitative research is crucial for understanding the deeper meaning and value of these needs. Specifically, in choosing a design direction, the mere identification of a need does not ensure that it will effectively meet that need in practice. Qualitative insights are essential for gaining a nuanced understanding of how these needs manifest in real-world scenarios, allowing for more informed and contextually appropriate design decisions.

Top 5 Transformations with the highest 'Relevance'- ratings

No.	Desired transformations	Average Relevance rating (1-5)	Standard deviation (lower is better)
1.	It should be made easier to insert measurements and other information at the location of measuring into the system.	4.9	0.35
2.	Nurses should have better means to communicate with each other from a distance.	4.6	0.82
3.	Measurements should more be automatically processed from measurment tool to database/patient dossier.	4.5	0.83
4.	The search process of finding medication in the medication storage should made easier.	4.4	0.63
5.	Nurses should remotely (without being present in the room) have better access to patientvalues (e.g. heartrate/oxygenvalues).	4.4	0.83

Top 5 Transformations with 'Favorites' votes

No.	Desired transformations	Average Relevance rating (1-5)	Amount of 'Favorites' votes (higher is better)
1.	It should be made easier to insert measurements and other information at the location of measuring into the system.	4.9	8
2.	Nurses should have better means to communicate with each other from a distance.	4.6	8
3.	Measurements should more be automatically processed from measurment tool to database/patient dossier.	4.5	6
4.	Nurses should remotely (without being present in the room) have better access to patientvalues (e.g. heartrate/oxygenvalues).	4.4	5
5.	There should be better tools (relative to the now used piece of paper) to save memory aids (e.g. measurment values).	3.9	4

Figure 22: Visuals with overview of the results.

4.3 Evaluating design opportunities for robotics

An evaluation table was developed to function as a reflective tool for identifying potential design opportunities within this project. This table uses the desired transformations and implicit human needs outlined in Section 2.4, Understanding User Needs, as the basis for reflective assessment. As noted in the previous section, the table incorporates the proposed transformations suggested by the nurses, along with any integrations or modifications. The aim of the assessment process is to foster critical thinking and challenge preconceived notions to identify viable transformation directions for the project. This is achieved by reflecting on existing touchpoints, evaluating the most straightforward means of intervention, and considering the potential added value of robotics in facilitating these transformations.

Context touchpoints

Environmental elements involved in the realization of desired transformations can play a pivotal role in exploring intervention solutions. Thoughtfully utilizing existing contextual features can lead to innovative solutions that seamlessly integrate into healthcare settings. The KonneKt design by Job Jansweijer, shown in Figure 23, exemplifies this approach by leveraging existing windows in the environment to create an effective, embedded intervention that requires minimal additional components (Jansweijer et al., n.d.). Therefore, this step in the evaluation table has been implemented to encourage critical thinking about the localization and embodiment of design within the environment.

Simplest means of intervention

It is easy to fall into the common design trap of overcomplicating solutions when focused on a spe-cific design problem for extended periods. Complex designs could impede successful understand-ing and adaptation by users.

Figure 23: KonneKt uses colored foam shapes with suction cups to enable creative and playful interactions on windows between isolated children in child cancer hospitals (Jansweijer et al., n.d.).

Therefore, it is wise to brainstorm the simplest interventions that can effectively achieve the desired transformation. This is also particularly relevant when considering technological applications, such as robotics. If a simpler, easier-to-use, or more financially viable option is apparent, stakeholders are less likely to invest time and energy into developing more cost-ly solutions.

Innovation opportunities

The final step in concluding the evaluation table involves assigning design, technological, or engineering subdomains that suit the specific user needs. Like many steps in this evaluation, this is not an objective truth but rather a reflective exercise to identify the most suitable domain directions. This step provides an overview of the various directions that user needs could lead to. It is then the designer's responsibility to consider which user needs are best aligned with the developmental capabilities of the project.

Added value of robotics

Finding simpler and cheaper alternatives to robotics is almost always a certainty. However, the added value of robotics can make it a beneficial design option worth considering. To facilitate this evaluation, small description boxes are included in this step. These boxes describe the application of robotics, specify the type of robotics, and provide a brief description of the value it can bring. The different applications of robotics are based on the classifications and types of robots outlined in Springer's Handbook of Robotics (Siciliano & Khatib, 2016) and by Intel (Intel Corporation, n.d.). The aim of this step is to encourage value-driven thinking by examining existing applications and understanding how robotics can add significant value.

A visual representation of the evaluation table with these reflective steps as columns is depicted below in Figure 24.

Desired Transformations *[goals]*	**Implicit Human Needs** *[unmet needs]*	**Context Touchpoints**	**Simplest Means of Intervention**	**Added Value of Robotics**	**Design Opportunities**
What change in practice does the user seek?	*What unmet need does the user seek?*	*What touchpoints are present in the context?*	*What is the competition for robotics?*	*In what way can robotics add value to the transformation?*	*What field of design fits the transformation?*
Nurses should have better means to communicate with each other from a distance.	Communication Support Efficiency	Telecare alarm buttons Medical smartphone Phone at nursing post	Existing communication Upgrading the Telecare System	Tele-presence AI Agent Social Robots	Communication Devices
There should be better tools that serve as an extra pair of hands during the treatment of patients (e.g. holding things or pass tools).	Autonomy Efficiency Control	Medical tape Clamps	Creative improvised solutions (tape) Request assistance of a colleague	Robtic Arms Robotic Humanoids	Mechanical Design Robotics
There should be tools to gain better insight into completed measurements and tasks (e.g. from colleagues from the shift before).	Clarity Safety Confirmation	Electronic Health Record (EHR) Computer on Wheels (COW) Personal note sheet	Software design improvements Procedural changes to task	Perceptual Recognition AI Agent	Software design Artificial Intelligence
Nurses should remotely (without being present in the room) be able to better see what the patient is doing.	Clarity Safety Understanding	Patient room windows Bedside vital signs monitor Medical smartphone	Camera monitoring Motion detectors	Perceptual Recognition Tele-presence	Monitoring Devices Communication Devices
•••	•••	•••	•••	•••	•••

Figure 24: Partial representation of the evaluation table used to reflect on design opportunities.

4.4 Discussing the identified design opportunities

The evaluation table presented in the preceding section has provided valuable insights into potential design opportunities for robotics aligned with identified user needs. However, challenges emerge regarding the integration of these innovations within the defined scope of this project. Balancing between prioritizing prevalent user needs as expressed by nurses and adhering to the predetermined technological scope presents a critical consideration. This section will discuss the results of the evaluation table and elaborate on the challenges identified for the next phase of this project.

Design opportunities for robotics

The majority of the design opportunities for robotics appear to be concentrated on patient-related transformations within the list, see Figure 25. This trend can be attributed to the inherent value of robotics in facilitating remote, autonomous or simulative interactions for patient experience and development. Design opportunities in this space are particularly compelling due to the potential for analyzing performative relationships that can be formed with robots, exemplified by is Boudewijn Boon's (2020) research on 'Playscapes' with robot ball Fizzy.

However, as stated in the introduction of this thesis, this project will focus on the nurses as the target group, and therefore, design opportunities centered around patients will not be pursued.

Patient-focused transformations	Implicit human needs			Design opportunity	
Patients in isolation should have more means to have interaction (e.g. playing with other patients) at the hospital department.	Play	Joy	Belonging	Game design	Robotics
There should be (better) means for parents to interact with patients when they are not visiting (e.g. from home).	Mutuality	Love	Confirmation	Smart devices design (IoT)	Robotics
Patient rooms should be more lively and interactive for the experience of the patient.	Joy	Creativity	Spontaneity	Smart devices design (IoT)	Robotics
There should be (better) tools to calm down patients in patient rooms.	Trust	Support	Love	Smart devices design (IoT)	Robotics
There should be (better) tools to provide patients with more freedom of movement (e.g. an improved IV-walking stand).	Freedom	Play	Spontaneity	Product Design	Robotics

Nurse-focused transformations	Implicit human needs			Design opportunity	
Nursing tools (e.g. instrument-/nursing trolleys) should be brought to the nurse.	Efficiency	Spontaneity	Accessibility	Robotics	
Nurses should spend less time searching what medication to take from the medication room.	Efficiency	Accessibility	Clarity	Logistical Management	Robotics
There should be better tools, relative to the now used piece of paper, to save memory aids (e.g. measurement values).	Efficiency	Support	Clarity	AI assistants	Robotics

Figure 25: Overview of the transformations involving robotics as results from the evaluation table.

Design opportunities for robotics concerning nurses primarily involve the delivery of tools and reducing the time spent searching for items and equipment, as depicted in Figure 25. These desired transformations align well with the capabilities of robotics and are, consequently, already in development at Erasmus MC, as discussed in Chapter 3.1, "Technological Developments in Healthcare". Most of these initiatives are in early stages of development, but will most likely also see integration into the Children's Thorax Center ward over time. Therefore, pursuing these opportunities would be strategically unwise, given that the existing development projects are already ongoing and have gathered valuable insights. Additionally, given the limitations of this project, which include the absence of an initial predefined design or robot prototype for testing, it would be unrealistic to expect it to contribute significant value to this field of research. The only other potential desired transformation is the development of memory aid and tools for nurses. However, the link to robotics might be a stretch as it focuses on mental assistance, rather than physical activity that is inherent to robotics.

Most important needs of nurses

The results and analysis of the group feedback session highlighted the clear preference among the pediatric nurses for enhancements in reporting measurements and actions within the Electronic Health Record (EHR) system. These desired transformations received the highest number of 'favorites' and were also rated highly in terms of relevance. The nurses indicated that their feedback underscores a critical need for improved efficiency and accessibility in localized data input and data requests. This need is exemplified by tasks such as entering measurements into the EHR or requesting real-time vital values for specific patients. Consequently, these aspects should be prioritized as the primary focus for enhancing the practice. Other feedback results with high relevance and preference ratings vouch for improvements of interpersonal communication and memory aid. These additional transformations underscore the nurses' desire for enhanced communication and support in their bedside nursing practice.

Ultimately, the primary needs of pediatric nurses in this ward are efficiency and accessibility of data, with communication and support identified as supplementary areas requiring enhancement. These identified needs will constitute the central focus of this research and guide the design development process.

Conclusions for further steps

The prioritization of user needs should take precedence over adherence to preconceived technological frameworks. Failing to do so may result in design interventions that do not align with user requirements or that present overly complex solutions, which users may overlook in favor of simpler, existing alternatives.

The predominant needs for efficiency and accessibility of data in bedside practice do not appear to directly align with the application of robotics, presenting a potential conflict for the continuation of the research in this direction. Also given that secondary needs include interpersonal communication and memory support, it is evident that shifting away from the initial focus on robotics may be more appropriate. Therefore, the next phase of this project will involve redefining opportunities within the practice and considering technological adjustments to better address these needs.

Phase 2 | Define

Thus far, the research has yielded valuable insights into the phenomena observed within bedside nursing practice at the Children's Thorax Center, Erasmus MC. It has established a solid foundational basis for a deeper understanding of current bedside nursing practices, resulting in design opportunities that emphasize the predominant needs of nurses. However, from these research results, the next question follows: How to progress from the sense-making of the current practice to the creation of design?

> *"In design research, our interests lie beyond the present, because we want to make use of the levels of insight in order to move toward the future, for which new solutions (e.g. product, service,...) will be designed.*
>
> *- Sanders & Stappers (2012)*

The gap between the tangible present reality and ambiguous conceptual space of future design concepts often presents a challenging prospect for designers, as it requires a seemingly leap of faith. Following the approach presented by Sanders and Stappers (2012), this gap can be overcome by first projecting the levels of insight into a future view, which can then naturally lead to conceptualization. This approach facilitates the creation of innovative design concepts that are both grounded in present sense-making and forward-projecting, enabling the development of solutions that effectively address emerging needs and challenges.

The second phase of this project aims to define a design direction that is aligned with a desired future state for bedside nursing practice at the Children's Thorax Center at Erasmus MC. This outlook on the future practice will be established by gaining a profound understanding of the various dimensions inherent in nursing practice, subsequently discussed and reflected upon through a generative session involving nurses. Ultimately, leading to the adjustment of the technological focus and formulating design directions that integrate the practice outlook of nurses with the potentials offered by technology.

Chapter 5 |
The dimensions of the nursing practice

An effective approach to facilitate the analysis and generation of potential design directions involves examining nursing practice through its various dimensions, as depicted in Figure 26. This dimensional analysis draws inspiration from multidisciplinary sciences that are involved for integrating technology solutions into healthcare practices. Fields such as engineering and technological sciences play pivotal roles as developmental enablers in the creation and implementation of design interventions. This technical perspective not only aids in the practical realization of interventions but could also serves as a valuable lens for design research, providing a physical viewpoint on the targeted practice. This approach can be extended to encompass behavioral, social, and cognitive sciences, which contribute a human-centered focus to the analysis of a specific practice.

Design interventions are primarily envisioned within a specific dimension of practice, but inevitably partake in the other dimensions through their manifestation and interactions within the practice. For instance, a robotic vacuum cleaner designed to automate repetitive cleaning tasks primarily addresses the physical dimension of home cleaning practice. However, its introduction into the practice induces changes in people's behaviors and attitudes toward cleaning processes and environmental cleanliness.

This analysis of various dimensions within a practice assists designers in generating novel design directions and uncovering previously unseen implications inherent to the practice.

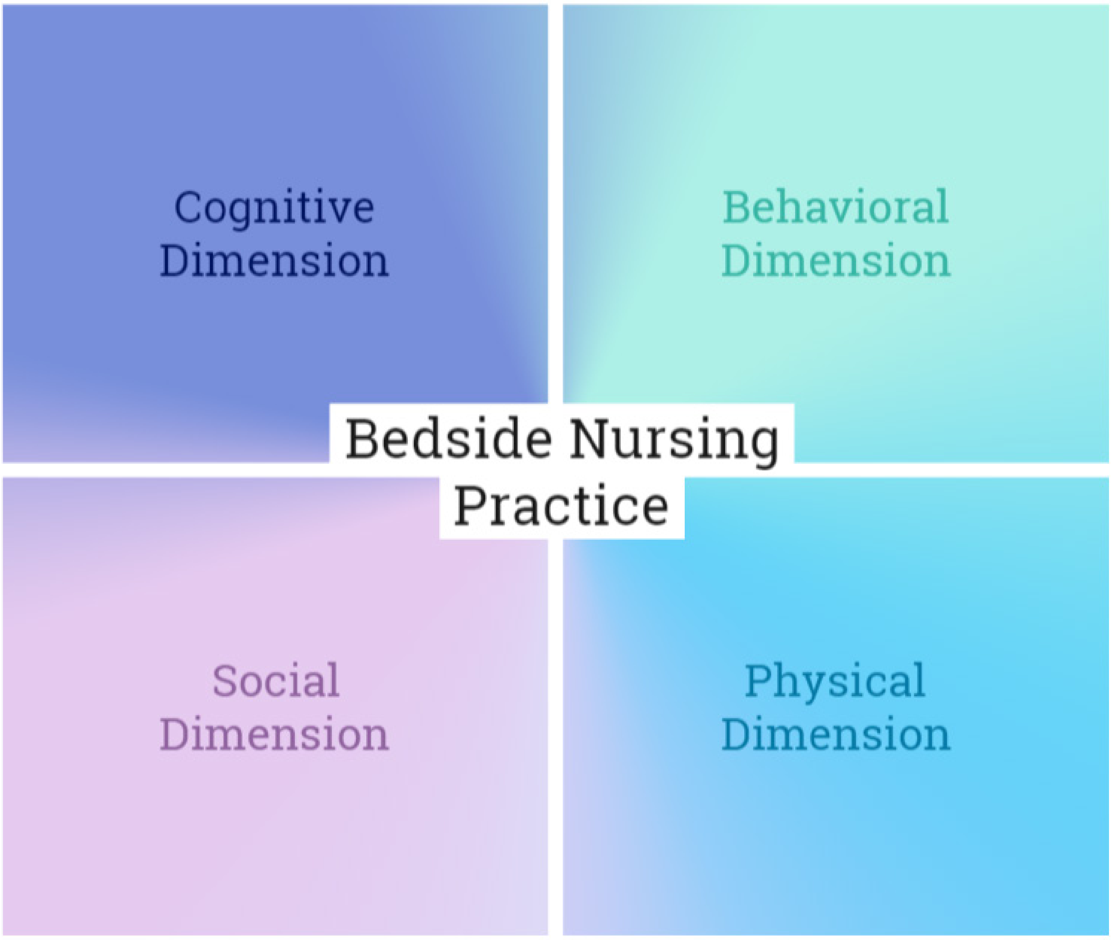


Figure 26: The four dimensions of the nursing practice.

5.1 The Physical dimension

The physical dimension of bedside nursing is predominantly characterized by the ‘movement’ involved in the practice. For nurses, this entails physically demanding tasks such as frequent traversal between rooms within the ward and moving patients (e.g. lifting and pushing wheelchairs) who lack independent mobility. Beyond the nurses, this dimension encompasses logistical interactions, ranging from medication delivery to stocking supplies, food and beverages for patients, visitors, and personnel. Furthermore, it encompasses the physical capabilities and constraints of individuals, artifacts , and environments. Examining the conditions under which these physical manifestations occur within the practice yields valuable insights into the causes and rationale behind desired changes. For instance, the behavioral instance of nurses deciding not to use the Computer on Wheels (COW) stems from practical considerations like the physical size of the COW and the spatial limitations posed by doorways and patient rooms.

Figure 27: The physical dimension represented by a nurse moving a weighing scale around the ward.

The value of robotics for this dimension

Robots are characterized for their ability to provide mechanical assistance by automating repetitive and physically intensive tasks. As such, robotics represents a suitable technological field for enhancing the physical dimension of the nursing practice.

The primary challenge within the physical dimension lies in identifying novel applications that offer distinct value for specific areas within the bedside nursing practice. Numerous robotics initiatives already exist in the healthcare industry, including those within Erasmus MC, as detailed in Chapter 3.1, Technological Developments in Healthcare. Consequently, the most promising applications of robotics have already been identified, researched, and are in various stages of development.

Furthermore, when comparing the Children's Thorax Center with other hospital wards, the physical demands of nursing practice differ due to the nature of activities specific to the patient group. Given that a significant portion of patients in this ward are young children, who are generally lighter and easier to move compared to debilitated adult patients, the physical intensity of moving patients is lower. On the other hand, nurses have noted that children tend to be more dependent and require frequent attention, necessitating more frequent trips to patient rooms.

Projecting this dimension into a future

The bedside nursing practice is set for significant transformation through the introduction of robotic interventions designed to assist and automate physical activities. Robotic storage installations within hospital departments will automate processes such as packaging, distribution, and collection. Patients, nurses, and other caregivers will benefit from robotic cranes, hospital beds, and automated wheelchairs that facilitate movement without requiring physical exertion. Delivery robots will autonomously navigate between hospital wards, enhancing the efficiency of logistical operations for medical supplies and hospital catering. There is even potential for locally-assigned delivery robots capable of fulfilling individual requests from nurses within specific wards.

In a future where robotic integration into healthcare practices is fully developed and optimized, the physical strain traditionally experienced by the people in practice could become a thing of the past. However, the introduction of more complex, intelligent, and dynamic artifacts may pose new challenges in other dimensions of nursing practice. The development of these innovative interventions will necessitate extensive experimentation through trials, iterative design processes, and overall adaptation of the practice as a whole.

Nevertheless, interest in healthcare robotics is growing amidst challenges such as staff shortages and increasing demands. Consequently, it is likely that the physical dimension of bedside nursing practice will undergo a revolution with the widespread adoption of robotics in a foreseeable future.

5.2 The Social dimension

The social dimension of the nursing practice encompasses the intangible relationships among people, artifacts, and environments. Healthcare practices are fundamentally built on human affections and connections, which are established through relationships and shared meanings over time. This dimension includes cultural and societal norms related to various aspects such as health, parenting, professional care, and privacy. These social aspects of practice are especially pronounced at this ward, where patients are vulnerable children with critical health conditions, necessitating high parental involvement and affections. With changes in cultural and religious values influencing care, nurses must adapt to a more diverse and rapidly changing social practice. Technological interventions support individuals within the cultural dimension of nursing practice, ranging from guiding hospital visitors to their destinations to assisting patients during mental rehabilitation. This section will closely examine interventions developments and explore a future outlook within this dimension.

Figure 28: The social dimension being represented by a nurse comforting a child.

Technological development and initiatives

The digital revolution of recent decades has significantly transformed nursing practice, evident in the widespread adoption of digital platforms for medical administration and the use of mobile communication tools. Computers have become a crucial component in transdisciplinary medical care, enabling access and exchange of patient information via Electronic Health Records and other digital systems. Meetings and consultations can be conducted remotely through video calls, text messages, and emails.

Digital interventions have also transformed the practice for patients and parents. With personal access to online medical health records, they can monitor medical progress and status in real time. Family members and patients can regularly communicate with each other without needing to visit in person, enhancing connectivity and support.

Developments in robotics are also transforming the social dimension of nursing practice. As discussed in Chapter 3.1, Technological Developments in Healthcare, the robot Temi is one such robotic application being tested for social patient interactions at Erasmus MC. Trials with Temi are exploring its potential role in patient boarding, which involves addressing patients in waiting rooms and guiding them to the correct treatment or consultation room. The aim of these trials is to observe and learn how robotic interventions can alleviate nurses from time-consuming and inefficient tasks, such as patient boarding.

Another social robotic application is the robot named ‘Pepper,’ which has been used in 2018 at the Franciscus Gasthuis & Vlietland Hospital. Pepper assists nurses with administrative tasks and engages in social interactions with patients to perform health assessments during bedside care. The trials resulted in mixed reactions from nurses and patients, with the primary concerns being the unnatural feel of interactions with the robot, alongside privacy and safety issues (Van Beelen, 2019).

Finally, social robotics are used for accompanying and supporting people. Robot pets or robot animals are a type of robotic application used to provide social support for individuals with mental disabilities or lonely elderly. These robots are specifically designed for social interaction and fostering human-robot attachment, offering companionship and emotional support to enhance the well-being of their users (Zorg van Nu, n.d.; Vilans, 2024).

The social dimension in the near future

Given the inherent technical complexities of recreating social beings and the numerous unknowns still existing in human sciences, it will be challenging to foresee technological applications that surpass or are able to replace human interactions effectively in the next few decades. However, as technology advances rapidly, more complex social capabilities are becoming feasible, providing more effective social support and companionship.

Therefore, a future outlook on the social dimensions of nursing practice will likely involve technological applications for simple and singular social tasks, such as enhanced social communication for medical personnel and visitor navigation at hospitals. Meanwhile, interactive artificial beings will serve as tools for social support and the social development of patients, providing companionship and assistance in ways that complement human caregivers.

5.3 The Behavioral dimension

Nurses demonstrate a strong practical focus in their work, consistently selecting the most effective and efficient methods to provide optimal care to their patients. They excel in employing work-arounds and improvisation, drawing on their intuition and insights gained through extensive practical experience. The patient demographic, including children, presents a diverse array of behavior patterns that influence nursing practice. Newborns typically engage in behaviors such as crying, sleeping, and eating, which are essential for their fundamental needs of parental bonding, physical development, and exploration of their environment. Conversely, older patients often exhibit verbal and physical activity, seeking care that includes opportunities for learning and participation in activities. Furthermore, nurses must adapt their approach when collaborating with parents in shared-care settings. Parents may vary widely in their attitudes toward nurses and their level of involvement in the care process. This variability underscores the importance of nurses' flexibility and ability to navigate diverse familial dynamics in delivering care.

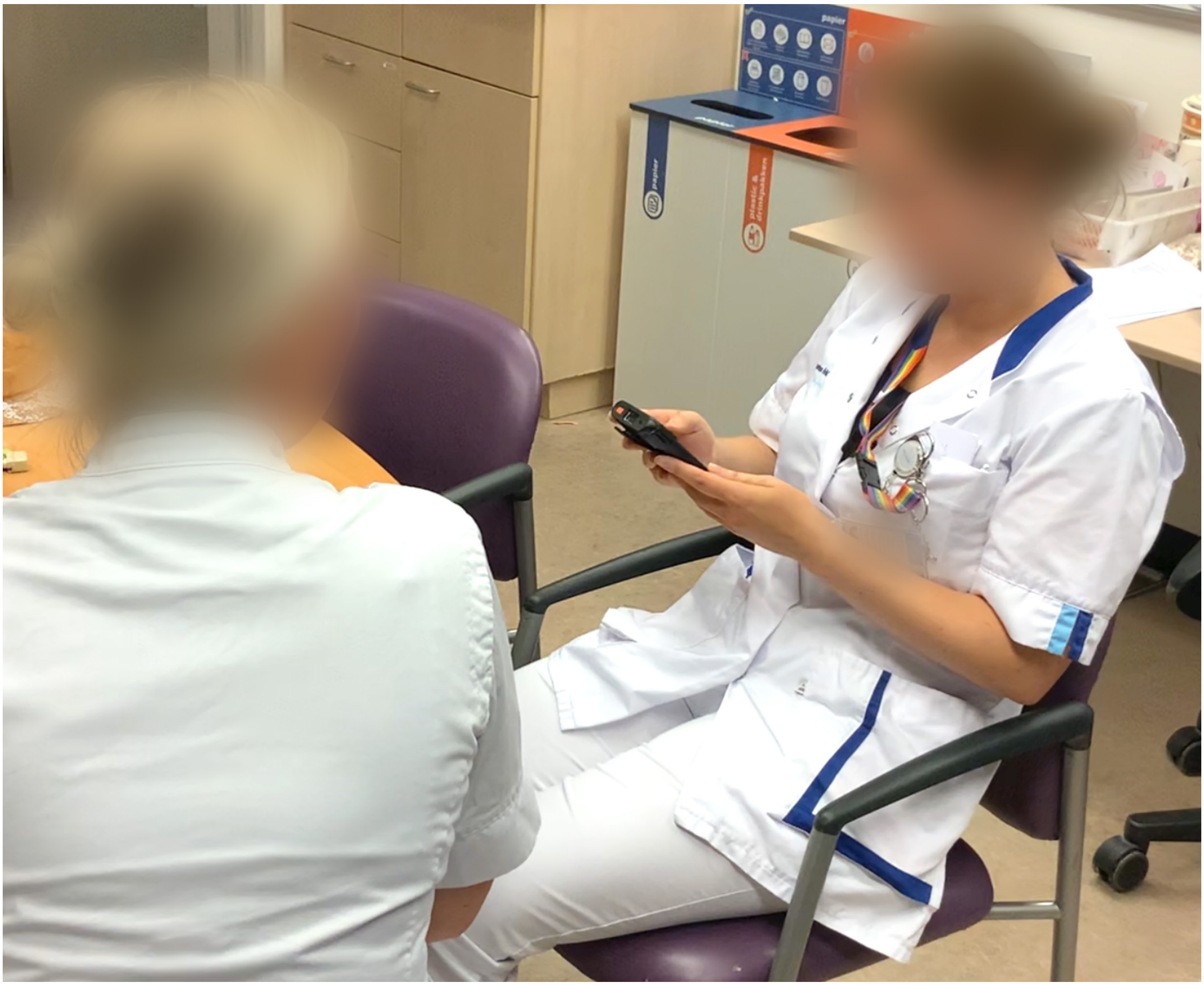


Figure 29: The behavioral dimension being represented by the medical smartphone demanding a nurse's focus.

Understanding behavior in practice

Before delving deeper into this dimension, it is essential to define and understand what is meant by behavior, as the term is used across various sciences with differing interpretations.

> *Behavior: an organism's activities in response to external or internal stimuli, including objectively observable activities, introspectively observable activities, and nonconscious processes.*
>
> *- American Psychological Association (2018)*

In this analysis, behavior is understood from the perspective of the behavioral sciences, particularly human psychology and anthropology. According to the definition provided by the American Psychological Association (2018), behavior encompasses both the observable actions and nonconscious processes of individuals in practice.

Furthermore, theoretical frameworks in behavioral sciences provide a deeper understanding of the possible causes and influences of behavior. The theory of planned behavior, as proposed by Ajzen (1991), explains that an individual's behavior is the manifestation of intentions rooted in their attitude, subjective norm, and perceived behavioral control. Following this theory, the effects of technological interventions on individuals in practice can be analyzed and understood.

Influences of technology on behavior

Technological interventions have profoundly transformed the behavior of individuals within the nursing practice. In current healthcare settings, nurses rely on the medical smartphones, patient sensors, and monitoring systems for vision on patient wellbeing. They entrust technological interventions for patient monitoring, allowing them to allocate their time to assist other patients or perform other nursing tasks. However, this reliance on technology compels nurses to frequently check their medical smartphones during practice, continuously being interrupted by alarms and notifications that divert attention from ongoing activities. As a consequence, nurses may assess risks for intervention remotely based on the information provided by technology, rather than relying on in-person medical assessment of the patient.

Furthermore, caregivers increasingly rely on sound machines, smartphones, or tablets to play white noise or other media for soothing patients. Such uses of technology reduces the direct interaction time nurses spend with individual patients, enabling them to care for multiple patients more efficiently. However, not all nurses embrace these technological advancements and efficiency-focused nursing practices. Many prioritize human interactions in their work, are reluctant to delegate nursing responsibilities to technology, or simply prefer traditional methods and routines over embracing change.

Learning from the behavioral dimension

All nurses prioritize their intention to provide the best possible care for patients, but the methods of delivering this care are contested within personal views and subjective norms among nursing colleagues. Moreover, technological interventions play crucial roles as mediators of nursing behavior. Developing understanding and building trust in such interventions is essential for enhancing the perceived behavioral control of nurses.

Nurses express apprehension regarding the growing reliance on rapidly advancing technology, which they perceive as difficult to keep pace with. A lack of understanding of these technological advancements makes it challenging for nurses to trust their application, especially given their responsibility for patient wellbeing. Therefore, future integrations of technology should involve a comprehensive understanding of its impact on nursing behavior in practice. Ultimately, technology should enhance the quality of nursing care rather than become replacements of behavioral control.

5.4 The Cognitive dimension

The final dimension focuses on the cognitive aspects of nursing practice. Unlike adult care, nursing children primarily involves high cognitive intensity due to their dependent nature. This is especially true for younger children who cannot speak or accurately communicate their feelings, such as pain or discomfort. Such patients demand continuous alertness and attention from nurses during practice, as they are unable to simply call for assistance when they need it. Furthermore, as detailed in Chapter 2.3, "Getting to Know the Children's Nurse," nurses are expected to continuously switch roles, multitasking as a compassionate caregiver, shared-care coordinator, and medical expert, while also engaging in ongoing observation, reflection, and planning.

Figure 30: The cognitive dimension being represented by a nurse using the note sheet to remember data.

Defining cognition

As the aforementioned dimensions of nursing practice focus on external phenomena and aspects, this dimension will center on the internal processes of the individuals involved in the practice. The discipline that encompasses such focus is cognitive science, which investigates the nature and function of cognition.

> *Cognition includes all conscious and unconscious processes by which knowledge is accumulated, such as perceiving, recognizing, conceiving, and reasoning.*
>
> *. - Encyclopædia Britannica (2024).*

Cognitive science is an interdisciplinary field that investigates the nature and function of mind and intelligence, incorporating disciplines such as philosophy, psychology, and more recently, artificial intelligence. Analyzing and understanding cognition in practice can be valuable for uncovering the internal causes of observable behavior, (inter)actions, and problems.

Nursing anxiety

Nurses develop cognitive resilience and intuition through training and experience in their practice. However, the cognitive load from intense multitasking and high responsibility can also take its toll on nurses. Research indicates that depression and anxiety are common among nurses (Li et al., 2023; Deck, 2022). Referred to as 'Preshift Anxiety' or 'Postshift Anxiety', these conditions involve nurses experiencing mild to severe feelings of fear or panic before or after their shifts (Tulp, 2023; Costa, 2023). These types of anxiety were also mentioned by nurses participating in this project's research activities. The causes of such anxiety can vary among individuals, from traumatic experiences to combinations of mental stress and overworking.

Interventions for cognitive support

There are a multitude of initiatives and tools that serve as cognitive support for patients during their hospitalization. They can be educative materials such as puzzles, books and games, or even aforementioned robots (e.g. Pepper or robot animals) that encourage cognitive development. Then there also hospital initiatives aimed at rewarding patients for completing treatments and medical milestones, such as the Kanjerketting (2024) or the Tikkiering of Stichting Hartekind (2024).

Interestingly, despite the evident challenges posed by cognitive load for nurses, there is a notable absence of innovative interventions aimed at improving this dimension for them. Nurses primarily rely on traditional yet effective techniques, such as using note sheets during their practice as cognitive aids. These note sheets, as discussed in Chapter 3.2, "Artificial analysis of the practice", are simple pieces of paper on which nurses jot down patient information from the EHR before the shift for informational reference, and new patient data during the shift as reminders for later input into the EHR.

Furthermore, technological interventions such as vital monitoring systems and EHRs have eased the burden on nurses by automating and structuring some of their activities. However, these technological additions also have negative side effects on nurses, such as overstimulation from signals and necessitating a divided cognitive focus across more aspects of their practice. Each new addition to the practice demands additional time and energy investment from nurses to fully familiarize themselves and master the innovation. Coupled with increasing workloads and longer working hours resulting from staff shortages, this situation can become mentally overwhelming for nurses. Therefore, perhaps technological interventions should be designed to support nurses in managing their cognitive load. Developing more effective tools that require minimal effort could help alleviate mental burdens and freeing their mental capacity.

Chapter 6 | Bridging the present with a future

Proceeding with the approach of Sanders and Stappers (2012), as discussed in the introduction of Phase 2, design creation takes place through what they call “bridging” the gap from the present to the future. This process involves traversing the various sense-making levels, facilitating the emergence of diverse conceptual perspectives. These perspectives can range from transformative big ideas that revolutionize entire practices to minor ideas that manifest in subtle design adjustments. The first step towards these conceptual perspectives is to define a future vision of the bedside nursing practice at the Children’s Thorax Center, based on the gathered sense-making insights. This vision serves as a guiding framework for subsequent design efforts and will be aligned with the nurses through a generative session. This collaborative session aims to refine and validate initial design ideas and a future vision, ensuring they are responsive to the practical needs and preferences of the end-users.

Ultimately, this chapter will discuss the process of ‘bridging’, which creates the platform for design conceptualization in the next phase.

6.1 A future perspective on the practice

Bridging the gap from research to design across the various levels of insight in current practice ensures the development of a comprehensive future vision. Sanders and Stappers (2012) discuss that bridging the present-future gap at different sense-making levels leads to ideas of corresponding scope, see Figure 31. For instance, addressing an issue at the data level might involve observing disruptions caused by feeding pump alarms and proposing a solution such as adding a mute button. In contrast, bridging at the knowledge level could entail identifying patterns of overstimulation that require systematic addressing within the entire bedside practice. This multi-level approach involves zooming in and out on phenomena within practice, which enhances understanding and provides guidance for design development during conceptualization stages. This section will explore this multi-level process of bridging, aiming to establish a cohesive future perspective to guide further development.

Bridging at the data level

The data generated from observations during job shadowing activities provide detailed recordings of phenomena occurring in bedside nursing practice. Consequently, projecting this data into the future at different sense-making levels can inform various changes to the practice. To illustrate how this process of bridging is accomplished, the following example is shown of a phenomenon observed and discussed with the nurses related to the medication collection process at the ward.

During the first job shadowing activity it was observed that nurses spend a significant amount of time searching for medication in the medication room. Currently, medication is stored in tall grey closets with drawers labeled with the exact name of the medication. One nurse explained that the medication storage unit should be automated, such as implementing a vending machine system.

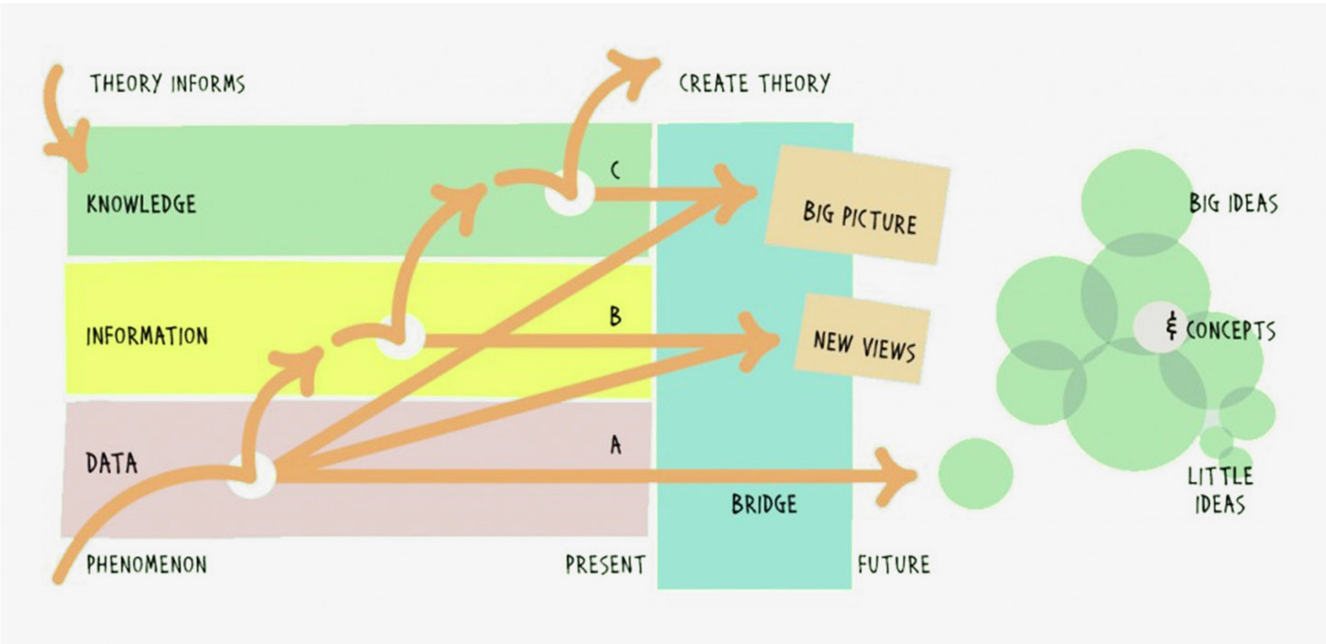


Figure 31: How to bridge the gap between the present and the future across different levels of understanding to generate designs (Sanders & Stappers, 2012).

Bridging at the information level

Zooming out to the information layer through applying interpretation and analysis reveals underlying problems that can be addressed with more abstracted design concepts.

The observed encounter at the medication storage may indicate nurse frustration with the ordering process and the labeling of the medication drawers. Nurses may struggle with mismatching the medication name in their mind with the actual name used on the labels. On the other hand, this process consumes time that could otherwise be spent on bedside care activities. A potential solution to this issue could be the implementation of a voice-controlled location system using LED lights, which would highlight the specific drawer containing the requested medication and speed up the searching process.

Bridging at the knowledge level

The final level of knowledge involves placing information within the broader context of practice. At this level, connections are drawn with other information, and overarching problems and needs are identified. This stage aims to integrate findings from specific observations into a comprehensive understanding that informs broader ideas for improvement of the practice as a whole.

For instance, the frustrations associated with the medication collection process are indicative of the underlying pressure and stress experienced by nurses. These healthcare professionals are responsible for multiple patients, and the increasing emphasis on efficiency and effectiveness exacerbates their stress levels. When nurses are unable to keep a direct line of sight on their patients and are diverted from providing bedside care due to time-consuming tasks, their stress is further compounded. Therefore, the perceived lack of control over patient wellbeing and the overburdening of tasks may represent overarching problems that potentially manifest in the phenomena observed at the medication storage. Solutions should entail a cohesive system of interconnected devices designed to aid nurses in patient management and task alleviation. This system could include automated delivery and collection robots integrated with a personal nursing assistant, embedded into a digital network within the ward.

Combined future perspective

The projections derived from the sense-making levels are combined into a unified future perspective, as illustrated in Figure 32. Due to the complexity and breadth of insights across these levels, it is impractical to reflect on every detail during a generative session with nurses. Consequently, certain nuanced insights are deliberately left out or simplified of this projected vision. The primary objective of this future perspective is to highlight potential technological solutions aimed at addressing the primary user needs identified during Phase 1. This focused approach ensures that the generative session is structured around reflective design thinking of solutions that can effectively enhance the bedside nursing practice at the Children's Thorax Center, Erasmus MC.

The projected solutions, which represent the primary user needs as shown in Figure 32, begin with the integration of a cohesive digital network of interconnected devices. This network serves as the tangible manifestation of the conclusions drawn at the knowledge level, addressing the fundamental issues of care control and task overburdening faced by nurses. In this future perspective, examples of interconnected devices include smart measurement devices designed for direct data input into the EHR, a personal nursing assistant serving as operating tool for the interconnected network, robotic storage units for item collection, and delivery robots for transporting items. This selection of possible design concepts is determined based on the bridging on the data and information levels, representing the primary insights gathered from the collected research data.

It is crucial to acknowledge that this projection represents a perspective on the future state of bedside nursing practice at the Children's Thorax Center, rather than the definitive future vision. The future perspective presented here represents a collection of snapshots of bedside nursing practice at this specific ward, derived from the subjective perspectives of nurses and the researcher involved in the study. This distinction underscores the speculative nature of forward-looking design exercises, which aim to inspire and guide innovation while remaining responsive to evolving insights and user feedback. Because in the end, even designers do not have the power to foresee how the exact future practice will look like.

Note that the presented perspective is grounded in current technological developments and the state of practice at the time of this research, with a timeframe for realization anticipated within the coming decades. More detailed information on the feasibility of implementing these advancements in the projected future can be found in Chapter 10.3, Roadmap.

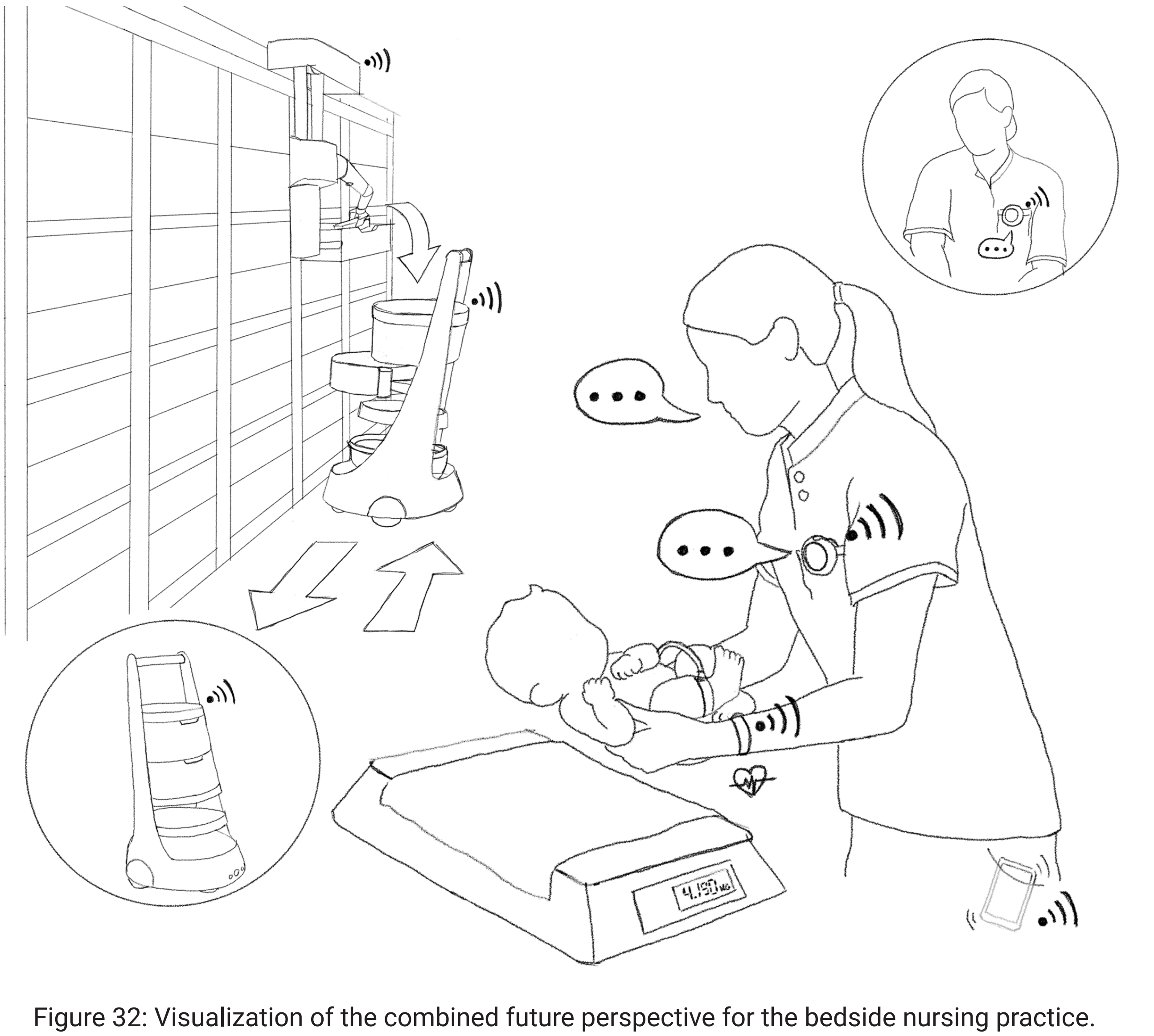


Figure 32: Visualization of the combined future perspective for the bedside nursing practice.

6.2 Generative session

The research activities in Phase 1 have led to valuable explicit and observable knowledge of the actions and statements of nurses in practice. However, following the principles of generative design research presented by Sanders and Stappers (2012), deeper knowledge can be discovered by enabling people to make tangible expressions of their thoughts and feelings, as illustrated in Figure 33. One such technique is the utilization of generative toolkits, which are sensitizing materials designed to guide participants through predetermined activities in their practice. Employing these toolkits with nurses can prove to be valuable in guiding discussions and finding alignment with the previously discussed future perspective. Consequently, a generative session was arranged with nurses to reflect on potential design direction and express their knowledge, feelings, and dreams regarding a future perspective of their practice.

Activity setup

Three nurses were invited to participate in an one-hour generative session conducted in a meeting room at the Children's Thorax Center ward. The participants were contacted through the nursing contact at the ward and were informed about the session plan in advance via email. The session was structured with the first half dedicated to reflecting on three design directions, followed by the second half focusing on generatively projecting onto a future perspective of bedside nursing at this specific ward. Research data were collected through filled-in toolkit sheets and audio recordings, which were subsequently transcribed into text transcripts for analysis.

Figure 33: Picture of the generative session at the Children's Torax Center, Erasmus MC Sophia.

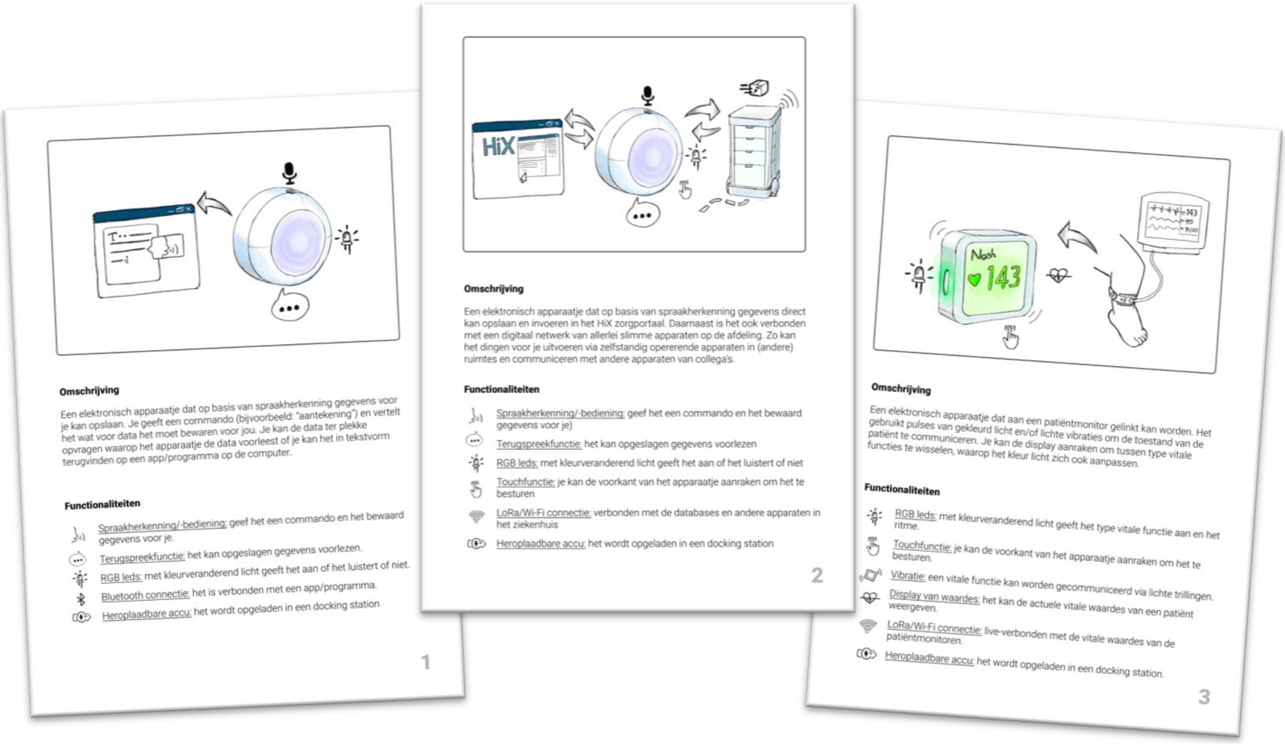


Figure 34: The design cards used for the reflection exercise on design directions.

Reflecting on design directions

In the first half of the generative session, three 10-minute rounds were allocated for design reflection, during which the nurses were provided with design cards containing a drawing and description of a specific design direction, see Figure 34. Design possibilities were discussed in previous research activities, but only resulted in general surface aspects of how such a design should look like. By presenting the participants defined designs on cards, they are sensitized to give more specific feedback and reasoning. Therefore, the aim for this exercise is to have nurses reflect on design directions facilitated by the incentive of the design cards.

The first design card featured a wearable device designed to facilitate note-taking during practice through speech-to-text conversion. This design direction aims to reduce the cognitive load associated with data management for nurses during bedside nursing. It is positioned as a technological advancement over the currently used paper note sheets, automating the organization of notes and reminders into a software platform.

In the subsequent round, the nurses received a second design card featuring a similar wearable device designed for data management during nursing practice. However, this advanced version is integrated into the Electronic Health Record (EHR) system and utilizes speech and language recognition models to fully automate the data reporting process for nurses.

The final design card presents a portable device designed to communicate live patient values. This design direction is aimed to establish a direct connection between the nurse and the patient, providing real-time updates on the patient's status to enhance the nurse's situational awareness.

Figure 35: The toolkit sheet used for the generative exercise for a future perspective.

Generative exercise for a future perspective

The second half of the generative session was dedicated to generate insight into how nurses envision the future of bedside nursing at their ward. A toolkit was assembled for this exercise, consisting of an A3-sheet along with a selection of crafting materials and drawing utensils such as colored markers and pens, see Figure 35. The toolkit sheet was structured into three numbered frames, which served as the framework for the exercise.

The first frame depicted the future perspective envisioned by the researcher, featuring the interconnected network of robots, wearables, and other smart devices. This frame served to introduce the generative exercise by sensitizing the participants to consider design manifestations and their positioning in practice. During this introduction, the researcher emphasized that the nurses should not concern themselves with the technological feasibility of these concepts and instead focus solely on what and they would find desirable in their future practice.

Subsequently, the second frame featured a cartoon depiction of a nurse interacting with a personal nursing assistant. The possibilities of a personal nursing assistant were found to be an interesting design direction in providing the main user needs identified up to this point in the research. Therefore, this visualization was aimed to direct attention towards the potential use of a personal assistant and stimulate contemplation on interactions with technology.

Following their observation and critical reflection on the first two frames, the nurses were instructed to articulate their personal vision of the future of bedside nursing practice in the final frame. They were given the option to express their perspective through drawing or writing, based on their preferred method of expression. Additional crafting materials, such as knick-knacks, were also provided to support the nurses in conveying their ideas tangibly if they chose to do so.

Finally, a 15-minute group discussion was conducted after the nurses individually completed their future perspectives. Each nurse was invited to share and explain their envisioned future, while the other nurses and the researcher posed critical questions. The aim of this group discussion was to observe the differences in the nurses' perspectives and understand the reasoning behind their proposed design ideas. This combination of individual and collective critical design thinking offered a deeper understanding of a desired future of bedside nursing at this ward.

Results of the session

The generative session was successful, providing valuable data on design directions and future perspectives for bedside nursing. Participants responded positively to the first two design cards featuring wearable devices for data management, recognizing their potential benefits. In contrast, the third design card, featuring a portable patient-nurse device, was disliked for adding to existing overstimulation and complexity.

The nurses communicated their future perspectives, with one drawing and the others describing their vision in writing. While they generally agreed with the future perspective, they expressed concerns about potential overstimulation from new devices. They prefer integrating existing touchpoints in the environment, focusing on accessibility through speech and visual data overviews.

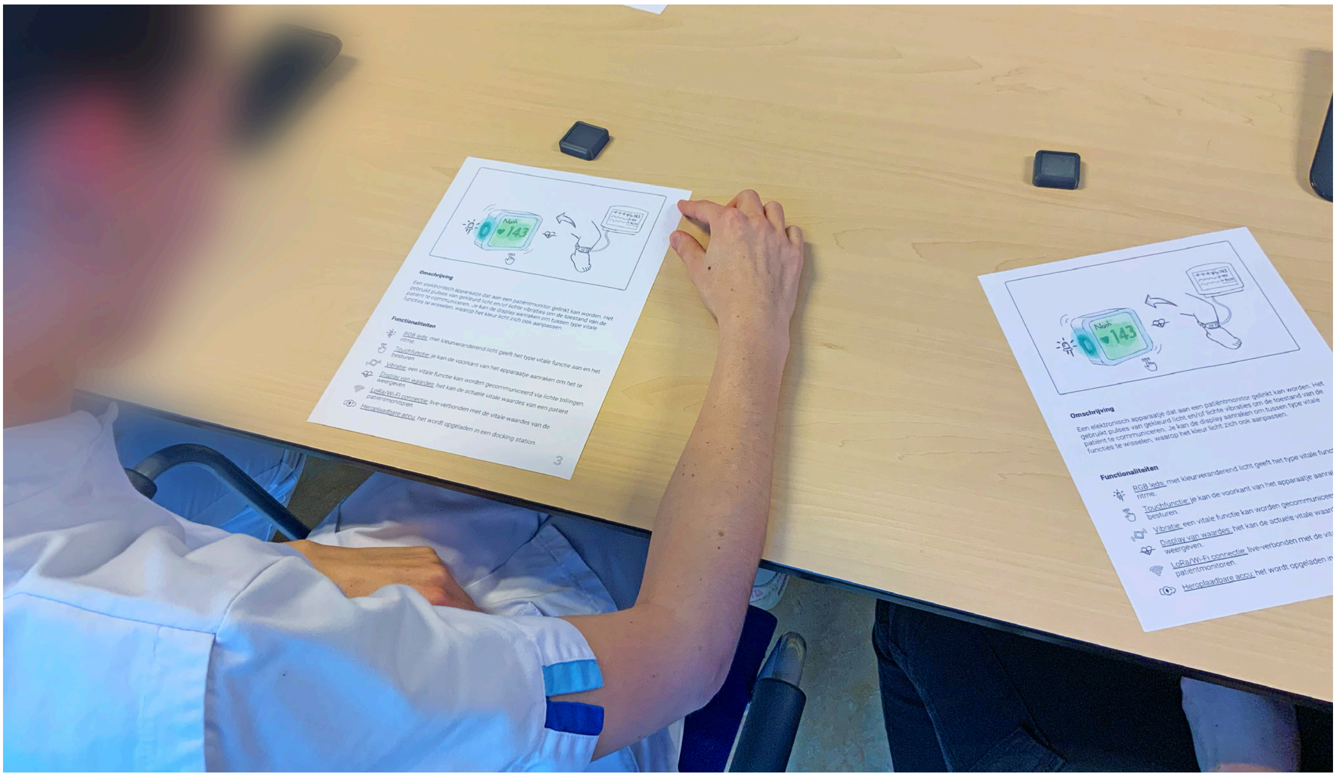


Figure 36: Picture of a nursing participant reading Design Card 3.

6.3 Analyzing generative session results

The generative session produced a wealth of new data captured in the audio recordings and completed toolkit forms. The process of extracting insights from this data begins with transcribing the audio recordings into text, enabling the analysis of quotations. Note that the entire session was recorded, and thus the transcript contained data of both reflective and generative exercises. Subsequently, the quotations from the transcript are filtered for valuable information and organized into an insight categorization table. The personal future perspectives expressed by the nurse participants are combined with the insights gathered from the transcript, resulting in a refined version of the future perspective of bedside nursing. This section will delve deeper into this data analysis process and present the finalized revision of a future perspective on the bedside nursing practice at the Children's Thorax Center ward.

Insight categorization table

The quotations containing valuable insights were extracted from the transcript and organized on digital Post-it Notes into a categorization table in Miro, depicted in Figure 37. Initially, these insights were categorized based on their relevance to either the problem-space or the solution-space of the research analysis.

The problem-space encompasses pain points in the current bedside nursing practice, which include examples of events or encounters that underscore the reasons for suggested changes in practice. On the other hand, the solution-space category pertains to future practice, where definitions of change are expressed through user desires, potential threats, and examples of means to achieve these changes. This category is divided into the following three different subcategories:

- **Desires** represent defined changes that are reactions to experienced pain points or expressions of personal wishes. This subcategory is divided into two clusters to distinguish between specific bedside activities and broader nursing practice.
- **Threats** include potential risks and focal points that should be addressed in designing future interventions. This subcategory is further subdivided into smaller clusters focusing on mental aspects of nursing practice, technological interactions, and considerations of privacy and safety.
- **Means** consolidates design ideas and examples of methods to achieve desired changes suggested by nurse participants. Insights in this subcategory are grouped according to intervention intelligence, manifestation, and data network.

The objective of the categorization table is to offer a clear overview of the various insights generated from the session, while retaining reference to the quotations of the nurse participants. The organization into distinct headers and columns ensures a clear differentiation of the specific value each insight holds for both research and design development.

The main takeaways

One of the primary takeaways from the insight analysis is the significant need for support in the cognitive dimension for nurses engaged in bedside practice. The nurse participants expressed that their biggest struggle in their practice is maintaining focus and control while multitasking. Disruptions to their workflow, such as missing tools and supplies, alarms, mistakes, and interference from people, can trigger a domino effect, leading to a loss of oversight in their practice. A substantial number of quotations in the pain points category highlight the cognitive load experienced by nurses, which manifests as mental stress during practice,

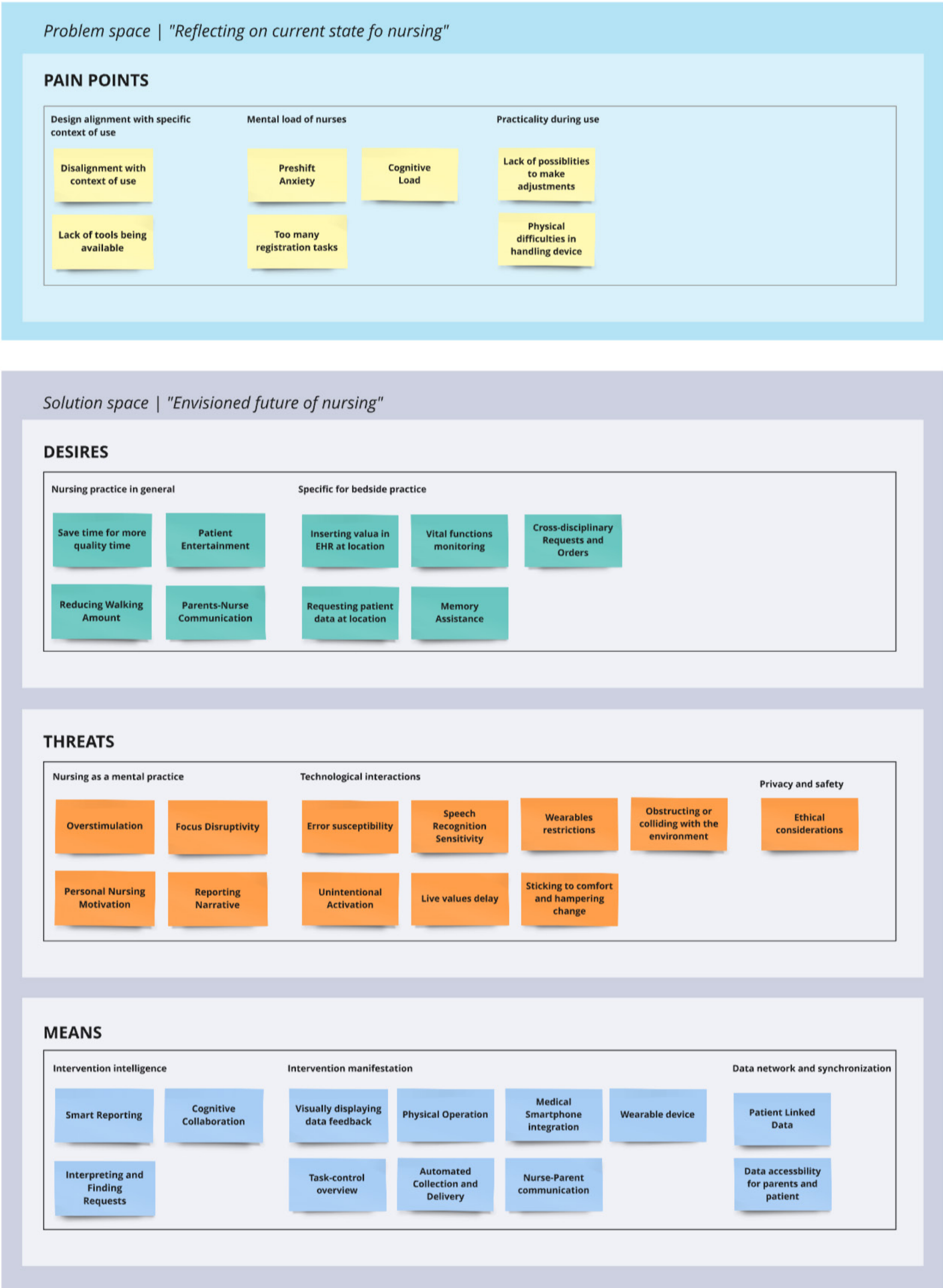


Figure 37: A simplified representation of the insight categorization table used for the analysis.

preshift anxiety, and an overburdening of tasks. For example, a nurse participant during the generative session expressed this as:

> *I can be really exhausted after a day's work and that doesn't have to be physically at all. For example, after evening shifts it takes me like 1.5 hours of unwinding my mind before I can go to sleep.*
>
> *– Nurse participant*

Nurses experience physical load due to the extensive walking required to collect supplies and to move patients. However, when asked which dimension is most critical in their practice, the participants emphasized the predominant need for change in the cognitive dimension.

They further supported this decision by emphasizing on experienced sensory overstimulation during the practice. The multitude of alarm sounds, coupled with the demands of aiding individuals seeking assistance, contributes to a heightened sense of sensory overload. This overstimulation, combined with the fatigue resulting from continuous their demanding profession, underscores the critical need for future interventions aimed at mitigating these sensory and cognitive stressors in the bedside nursing practice.

> *I am wondering if it is even worth it to add another device for real-time patient monitoring? Because we already have so many alarm sounds now that create a lot of noise. Adding even more would definitely overstimulate me!*
>
> *– Nurse participant*

Ultimately, it is crucial to avoid introducing unnecessary devices that add more stimuli to the nurses' environment. Future interventions should focus on utilizing or replacing existing devices with those designed to minimize cognitive stressors.

The final main takeaway from the insights analysis underscores the importance of local accessibility to networks and databases during bedside nursing. Nurses typically find administrative responsibilities burdensome, particularly the need to recall readings and observations later at fixed desktop stations. Despite the availability of Computers on Wheels in the ward, as discussed in earlier chapters of this thesis, nurses express strong dissatisfaction with the cumbersome handling of these computer. Instead, nurses advocate for the integration of measurement devices and easily accessible touchpoints within the practice environment for inputting and retrieving data from IT networks.

> *It would be nice if it were also possible to get something back when being in the patient room. Like when you are weighing a patient, that you can simply request the weight reading of yesterday on the spot and compare.*
>
> *– Nurse participant*

Revising the future perspective

The generative exercise highlighted that the nurse participants also envision a future involving a connected network of smart devices and digital systems, emphasizing the advantages of remote data control without the current limitations of location-boundedness. However, the nurses underscored in their personal future perspectives that the addition of more devices raises significant concerns for them. Instead, they advocate for the integration of direct connectivity into existing devices, particularly emphasizing the implementation of direct EHR connectivity of measurement devices such as weighing scales and vital monitors. This technology would take away the burden of nurses having to remember values and manually input them into a computer system.

Furthermore, the nurse participants elaborated on connected touchpoints for accessing the Electronic Health Record (EHR) and Quality Management System (QMS), as mentioned previously. One participant envisaged an interactive screen positioned on the wall within patient rooms, facilitating access to care plans and patient data for both nurses and patients' parents. In expressing their preference, the nurses emphasized a clear inclination towards visual feedback as opposed to audio feedback. They reasoned that visual interfaces are more efficient for taking in information a glance, contrasting with audio cues which may add sensory load in environments already prone to overstimulation.

The nurses are positive on the prospect of automation and spending less time doing inefficient tasks. However, the idea of delivery robots was met with cautious apprehension among the nurses, who expressed concerns over potential adverse effects within the ward environment. Their concerns are centered on fears that these autonomous devices could encounter difficulties navigating the bustling ward or inadvertently cause harm to individuals. On the other hand, the collection robot in the storage unit was received with more enthusiasm as it solves a specific nuisance for nurses and involves less risk in being in a confined space.

Finally, the design concept of the personal nursing assistant received favorable feedback from nurses. They appreciate its unrestricted accessibility as a wearable device and the potential for hands-free operation. However, nurses approach the idea of robotic assistance with caution, expressing concerns that such technology could potentially diminish their autonomy and control in patient care scenarios. They emphasize the importance of ensuring that any robotic assistance complements rather than supplants their decision-making processes. As long as these devices support nurses without imposing on their autonomy, providing intuitive and accessible assistance, nurses acknowledge the promising value that such innovations can bring to their practice.

6.4 The value of quality time in the nursing practice

“More quality time for nursing” emerges as a recurrent theme among nurses when expressing their primary aspirations for the future of their practice. This expression encapsulates their fundamental needs, originating from the knowledge and feelings experienced in current bedside nursing practice. It represents nurses’ dreams, underscoring the importance of comprehensively understanding this expression for fostering desirable innovations in the future bedside nursing practice. This section will focus on capturing the value of quality time in nursing practice by addressing the following questions: What do nurses mean with quality time? Why is it valued so much in the practice? And how can it be ensured in designing future interventions?

The primary objective of future innovation

The primary dimensional focus identified from the insight analysis is the development of interventions aimed at providing cognitive support for nurses in their practice. However, at the core of all future innovations should be the assurance and enhancement of quality time for nurses. This concept of ‘quality time’ is crucial as it embodies the primary value underlying the existence and operation of care practice, as depicted in Figure 38. Therefore, the following primary objective should stand central in the development of future innovation:

> *Nurses should be supported to have more quality time for actual nursing, rather than being occupied with other activities that detract from it.*

Quality of care

The first value of quality time revolves around the primary responsibility that nurses carry during their practice. Nurses articulate their primary responsibility as ensuring the provision of the best possible care for patients, which they perceive as encompassing the actual bedside care activities that enhance patients’ well-being. Therefore, when nurses express a desire for more quality time, they are essentially referring to dedicating more time to activities that they believe enhance the well-being of patients, rather than being occupied with tasks that detract from providing quality care.

Human interactions

Furthermore, human interactions are fundamental qualities of care practice. As established in Chapter 2.3, nurses are inherently social and empathetic individuals. They choose nursing as a profession to apply their medical expertise in the direct care of patients. This desire for human connection extends to patients and their families, who seek medical security fostered through understanding and trust. Therefore, human interactions constitute an integral part of quality time, and replacing these moments of interaction would diminish the overall value of nursing practice.

Motivation for growth

The third value of quality time encompasses the personal challenges and growth involved in the nursing practice. During the generative session, nurses expressed concerns that future interventions might diminish challenges of their practice. They are motivated by the personal development of skills and experience as medical experts. Following the Behavior Model of Fogg (2024), it through the correct use of prompts of future interventions that balance of ability and motivation can be maintained for success. Therefore, it is essential to include motivation and ability as determinants of quality time in the bedside nursing practice.

A focused mind

The final value describing quality time for nurses is the ability to maintain a focused mind to execute nursing tasks effectively and efficiently.

As discussed in Chapter 5.4, nursing requires extensive active mental processing, with nurses continuously reflecting on current situations and planning interventions ahead. Disruptions to this focus and workflow can be taxing for nurses and may detract from the quality of care provided. Therefore, when nurses speak of quality of care, they inherently emphasize the importance of maintaining focus and peace of mind during their practice.

Figure 38: The main values attributing to quality time in the bedside nursing practice.

Chapter 7 | Adjusting the technology focus

The process of bridging the present practice with a future perspective has led to a deeper understanding for design directions in bedside nursing practice at the Children's Thorax Center ward. Certain design directions are well-suited for the application of robotics, particularly in the automation of transportation and the collection of resources used in practice. However, as discussed in Chapter 5.1, robotics is largely confined to this physical dimension of the practice and is already being extensively explored and developed in existing initiatives, including those at Erasmus MC itself. Therefore, this chapter will critically reconsider the initial technology focus on robotics in light of the now established landscape of future aspirations in this practice. It will discuss the positional opportunities within the various dimensions of nursing practice and the dilemma encountered when maintaining a primary focus on robotics. Ultimately, it will conclude with a new technology focus and a design direction for the next phase.

7.1 Positional opportunities in practice

Strategic opportunities are analyzed to identify the most valuable design direction to pursue in the upcoming project phase. This process begins with determining the overall possible strategies available concerning both practice and technology. One effective method for this strategic evaluation is the creation of an Ansoff Growth Matrix (Van Boeijen et al., 2020). This matrix maps out strategic options along axes of development, which is useful in defining the overall strategy that will be followed for this project. With the overall strategy established, the next step involves analyzing existing technological developments in the different practice dimensions using a Perceptual Map (Van Boeijen et al., 2020). This analysis ultimately concludes on the best positional opportunities in the bedside nursing practice for new design development in this project's context.

Defining the development strategy

An Ansoff Growth Matrix was created to determine the general development strategy for the next design phase of this project, as depicted in Figure 39. The matrix features axes representing the degree of advancement in technology and practice, offering direction into both the current and the new. Generic strategies for development are positioned within each quadrant of the matrix, thereby facilitating a comprehensive analysis of potential pathways for progress.

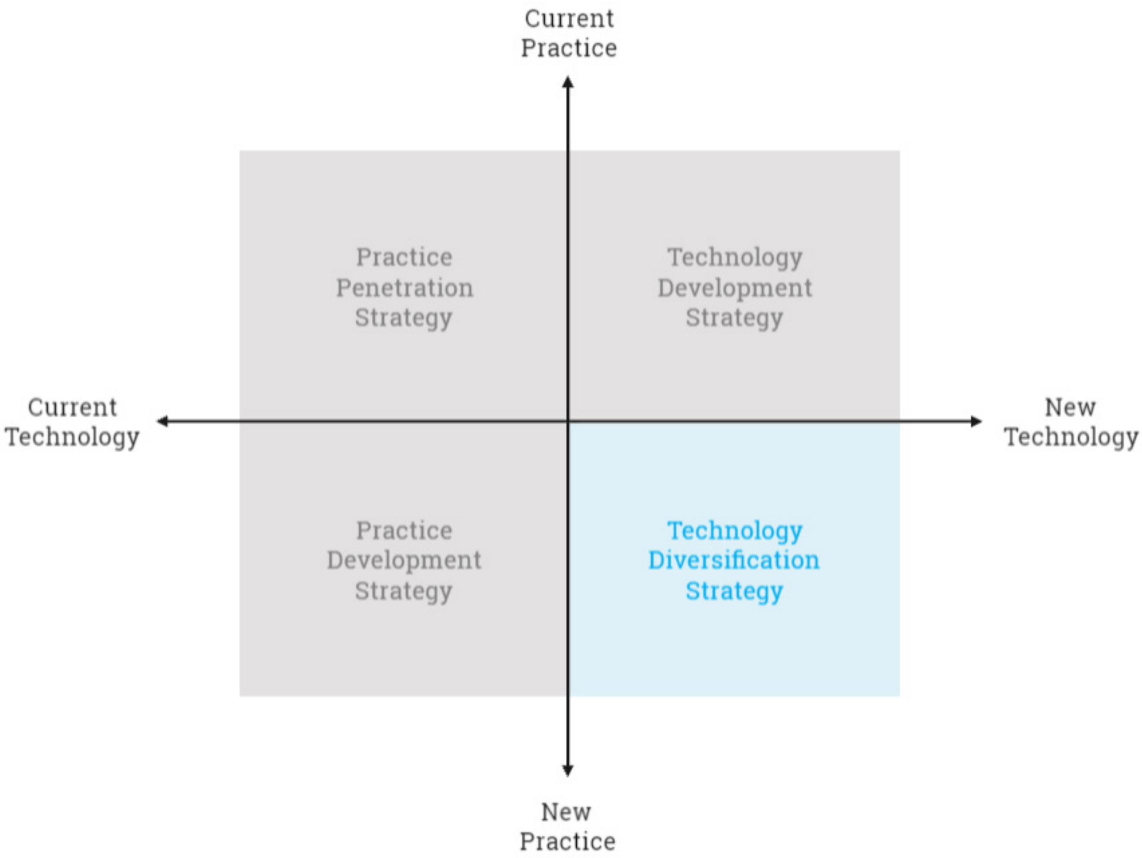


Figure 39: Ansoff Growth Matrix with the chosen development strategy highlighted in blue.

A Practice Penetration Strategy would be the safest bet, involving the least risk as it leverages proven technology and a well-defined design context within the current practice. However, discovering new value through the application of existing technology in the practice is challenging due to the extensive and expansive research developments that have already explored these areas, as discussed throughout this thesis.

While the Practice Development Strategy and Technology Development Strategy might have been explored briefly during the research phase of the project, the primary aim remains to generate new insights and awareness in designing technological interventions to improve bedside nursing practice. This project seeks a desired future perspective of the practice, utilizing new technological developments as supportive interventions. Consequently, the main overall strategy of this project is to find unexplored value through technology diversification in future practice.

Positioning interventions in practice

The development strategy of diversification through new technology and a future practice offers a general direction, but it does not specify a strategic focus within the practice itself. Perceptual Maps can provide such valuable insights into the segmentation of the practice, as well as the differentiation and positioning opportunities of the identified design directions (Van Boeijen et al., 2020). Therefore, a variant of the traditional Perceptual Map from marketing strategy is utilized to place (technological) interventions within the four dimensions of nursing practice, as illustrated in Figure 40.

In conventional marketing, Perceptual Maps are typically used to plot products or brands along two axes representing specific properties. However, for this practice-focused strategic analysis, (technological) interventions that are identified through this project are positioned on the map, with additional dimensions added to the quadrants. This approach provides an overview of how existing interventions are situated within the four dimensions of bedside nursing practice, thereby revealing potential positional opportunities for new technological developments in previously unexplored areas.

Identifying positional opportunities

The Perceptual Map reveals that robotics development initiatives are positioned prominently within the tangible aspects of bedside nursing practice. This placement is logical, as the primary value of robotic applications lies in their ability to replace or assist with physical tasks. Of particular interest is the observation that the majority of robotic initiatives in this practice are situated in the Physical dimension. This suggests that these technologies are designed for general use and application within the hospital's operational framework. On the other hand, robotic applications tailored for individual use appear to be targeted towards patients. This observation points to a positional opportunity for developing robotic applications specifically aimed at assisting nurses on a more individualized level.

The absence in personalized support for individual nurses is further highlighted in the cognitive dimension, where their primary means of support still revolves around traditional tools like paper for note-taking. Technological interventions involving artificial intelligence or other computational tools appear to be predominantly implemented within larger-scale systems and databases. While individual nurses do have access to these interventions through general desktops in rooms, medical smartphones or Computer On Wheels (COWs), the provision of personalized assistance and access at an individual level remains largely unexplored.

Therefore, the primary positional opportunity for this project seems to be at the individual perspective for nurses. Designing technological interventions for personal support and access at situations that arise at bedside.

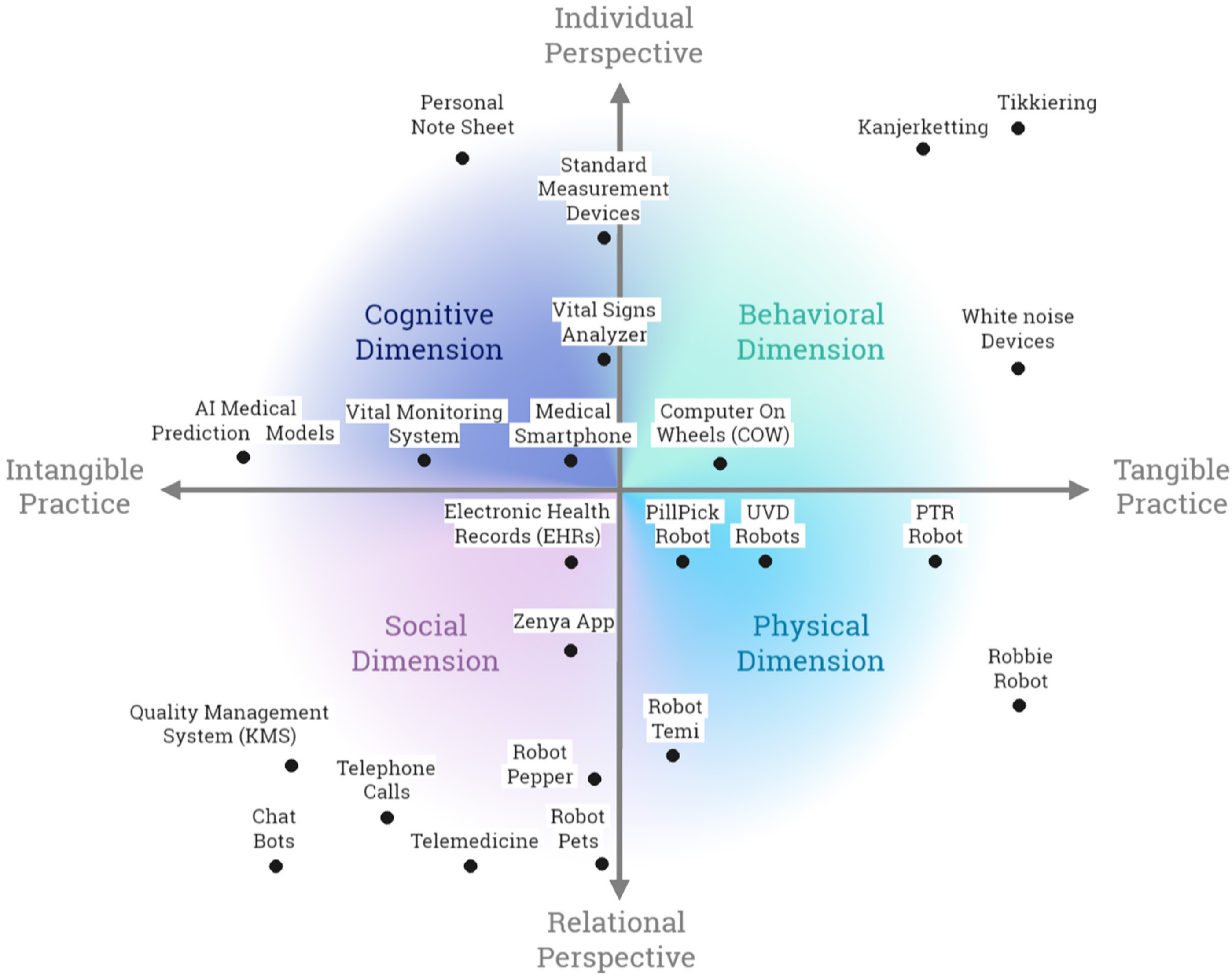


Figure 40: Perceptual map of interventions placed in the dimensions of the nursing practice.

7.2 A dilemma of robotics and practice

Robotics originated from the necessity to automate repetitive tasks in the manufacturing sector. Over time, the field of robotics has evolved to encompass more sophisticated applications across diverse industries (Siciliano & Khatib, 2016). However, it is the fundamental capability of robots to automate structured physical actions that remains their inherent value and strength. Research into the bedside nursing practice has revealed a spontaneous practice centered around human interactions. Moreover, as highlighted in the previous section, the primary opportunity for design development lies in supporting nurses in the cognitive dimension of their practice. This contrast between the initial technology focus on robotics and the realities of bedside nursing practice at the Children's Thorax Center ward forms the central point of discussion in this section.

Programming structure for spontaneity

One of the main challenges in integrating robotics into nursing practice is addressing the programmability of spontaneity. The behavior of robots is determined by the architecture used to program their operations, which is distinct from other software frameworks.

> *Robot architectures are distinguished from other software architectures because of the special needs of robotic systems. The most important of these, from the architectural perspective, are that robot systems needs to interact asynchronously, in real time, with an uncertain, often dynamic, environment.*
>
> *– Kortenkamp et al. (2016)*

Most robotics utilize the subsumption approach, a layered structure of state machines, as exemplified in Figure 41 (Brooks & Flynn, 1989; Siciliano & Khatib, 2016). This architectural approach provides a structured and predictable framework for the robot's behavior, enabling real-time reactions through actuations based on sensory inputs. Additionally, behaviors can be overridden; for example, a specific sensory input condition can interrupt ongoing actuation processes with another behavior.

This approach is easily manageable in predictable and controlled environments. However, as spontaneity increases in an environment due to numerous unpredictable factors, complex dynamics, and unforeseen events, it becomes significantly more challenging to preprogram appropriate responses. Other programming approaches, such as Behavior Trees, have been adopted in robotics to enhance simplicity, modularity, and reactivity (Colledanchise & Ögren, 2018). Compared to subsumption architectures and other state machine approaches, Behavior Trees are more scalable for complex tasks and easier to maintain for altering controllers. It is important to note that these architecture approaches are often combined in robotic applications, employing the framework that best suits designing specific sections of the architecture, see example in Figure 42.

Despite these advances, further development and optimization are required to integrate new AI frameworks into robotic applications, ensuring they align with the demands and spontaneity of healthcare practice. The stakes in healthcare practices are high, as they involve the wellbeing of humans. The nursing practice at the Children's Thorax Center ward includes numerous medical personnel and guests temporarily visiting the ward, children running and playing in the hallways, and vulnerable and critically ill patients frequently needing to be moved from patient rooms to treatment rooms. In such environments, robots cannot block important doorways or accidentally collide with children. This makes the process of testing, developing, and optimizing such robotic applications challenging and time-consuming, but ultimately necessary.

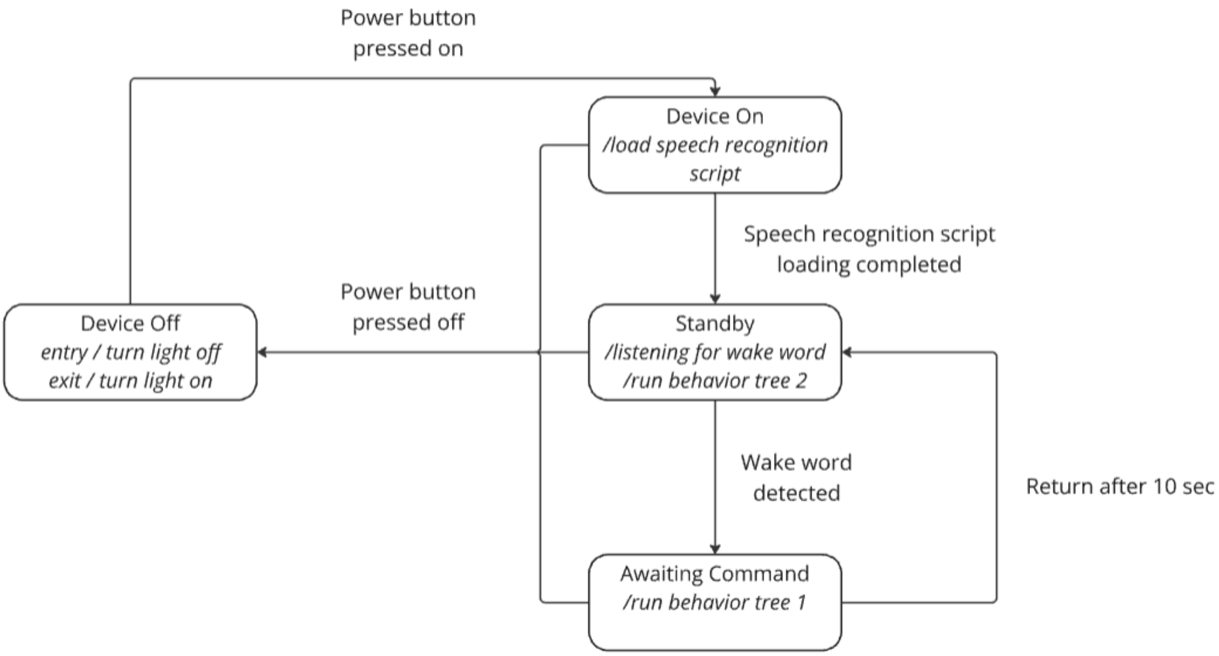


Figure 41: Example of a state machine diagram for a wake function.

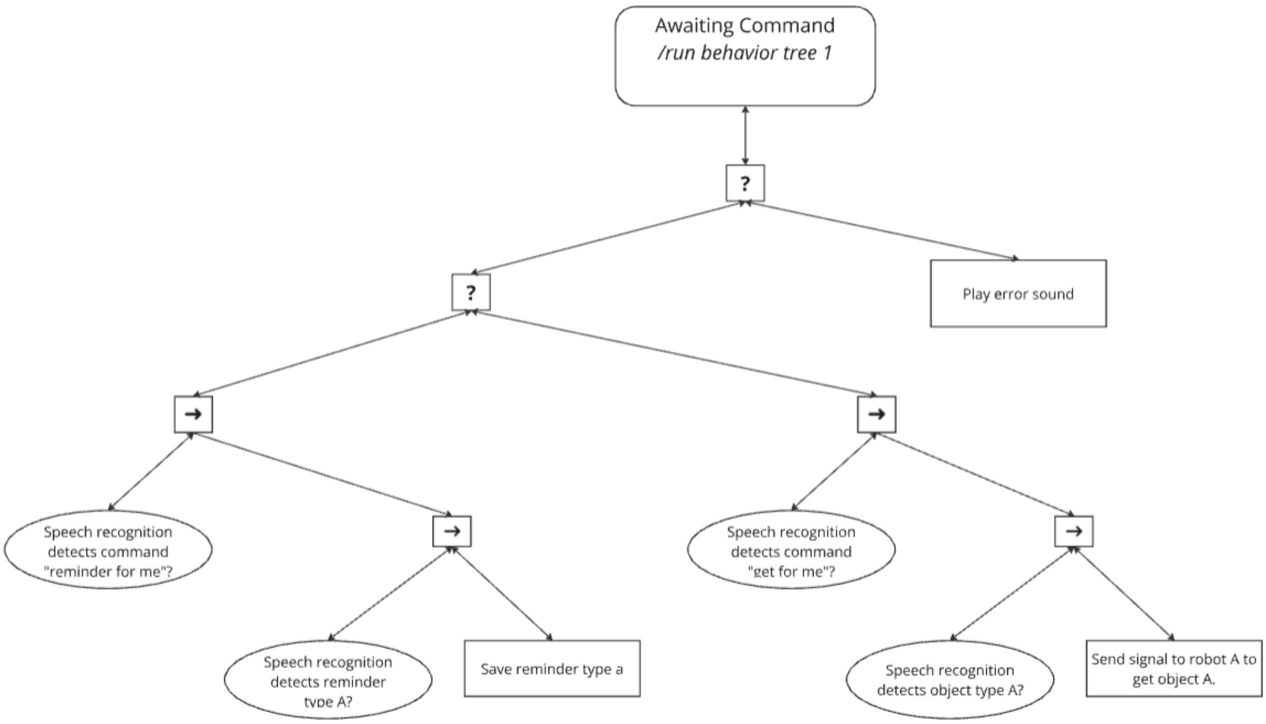


Figure 42: Example of a simple behavior tree for speech commands.

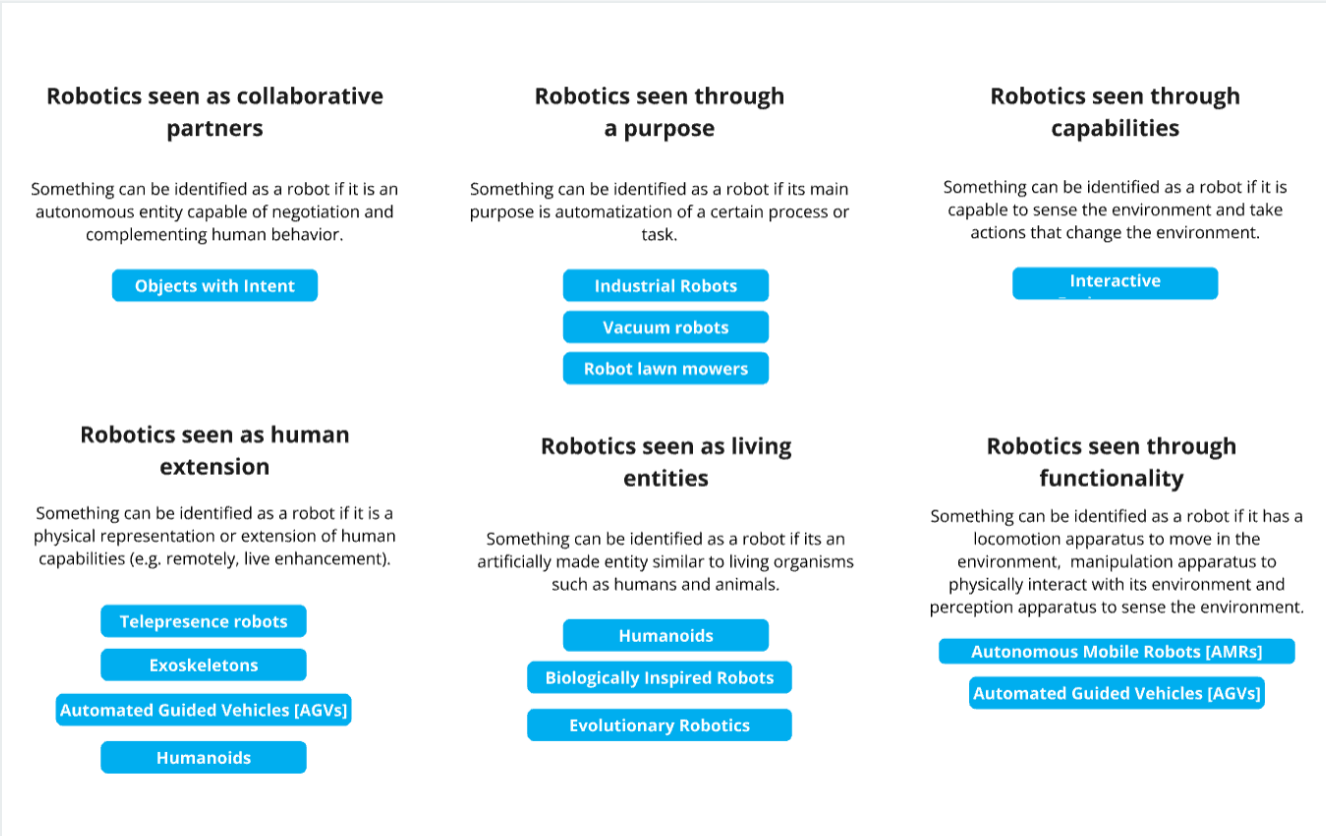


Figure 43: An overview of different perspectives on robotics.

Dimensional conflicts

Beyond the programming challenges involved in designing robotic behavior, a conflict arises concerning the primary dimensional needs identified by nurses in this practice. Nurses predominantly require support to meet the cognitive demands they face, as extensively discussed in previous chapters. However, when approaching this need from a robotics perspective, as initially undertaken at this project's creation, design possibilities appear constrained by the chosen technological focus. A deeper exploration of the definition and origins of robots can provide a clearer understanding of this conflict and clear potential pathways forward.

The term "robot" originated from science fiction depictions of mechanical humans in the late 1920s. However, actual applications of robots emerged several decades later, initially serving as numerical machines for precise manufacturing and remote handling of hazardous materials. Robots quickly evolved into essential tools driving the industrial revolution of mass production and precision manufacturing. These early industrial applications, now known as industrial robots, laid the foundation for further diversification of robotic applications across industries. Robotics have become more than their original industrial mechanisms, as illustrated in Figure 43. Nowadays, robotics can be found everywhere from unmanned space vehicles on Mars to robotic toys like the Furby in the hands of children.

> *Robots are programmed actuated mechanism with a degree of autonomy to perform locomotion, manipulation or positioning.*
>
> *– ISO (2021)*

Following the definition provided by the International Organization for Standardization, robots are inherently characterized by their physical manifestation and capability to interact with the tangible world. As exact definitions have been iterated upon throughout the years, robots have maintained their archetypical nature as actuated mechanical creations. While there may be some overlap, this physical nature of robots contrasts with the cognitive support identified as the predominant need for nurses in this practice, as illustrated in Figure 44.

Moving away from the focus on robotics

Ultimately, the physical constraints of robotics impose limitations on design explorations in the next phase of this project. As articulated in the design approach of this project, prioritizing a human-centered focus is crucial for developing interventions that genuinely support nurses in their bedside nursing practice, taking precedence over strict adherence to initial technology principles. Therefore, the decision has been made to pivot away from the technology-centric focus of robotics.

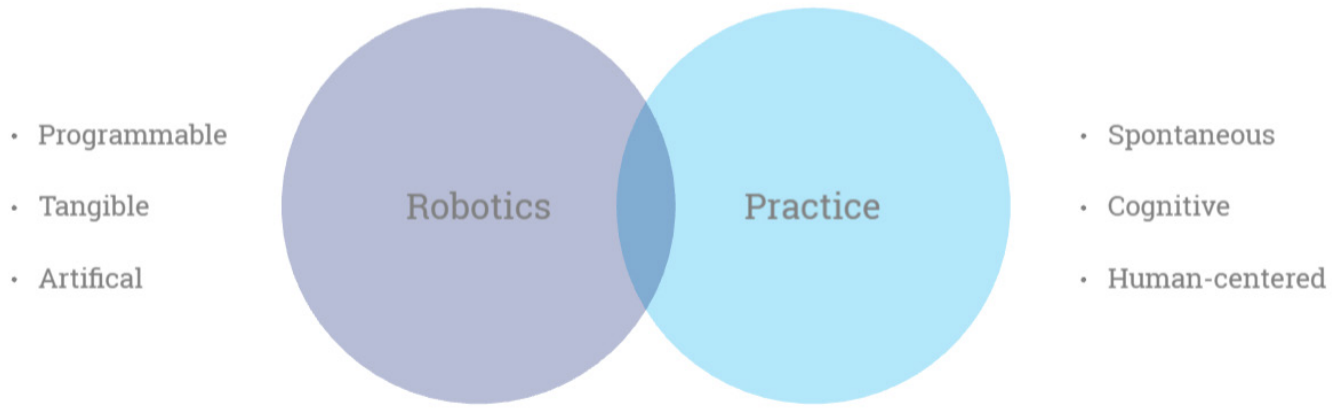


Figure 44: A visualization of the dilemma between robotics and the bedside nursing practice for further development in this project.

7.3 Pervasive computing

Now that the decision has been made to broaden and shift the technological scope away from robotics, what is a suitable technology replacement? The concept of Pervasive Computing might be the technological focus that aligns best with the established future perspective for bedside nursing practice at this ward. It implies the seamless integration of computational networks with pervasive access anytime and anywhere, utilizing any interactable format present in the environment. This aligns well with the primary need for unbounded accessibility and support that nurses projected in their future perspectives. This section will delve into Pervasive Computing, understanding its applications and exploring its value in developing designs within the future perspective outlined for bedside nursing practice.

The vision of Ubiquitous Computing

Pervasive computing evolved from Ubiquitous computing, a visionary concept introduced by Mark Weiser in the late 1980s. The concept of Ubiquitous computing revolves around the seamless integration of technology into everyday activities (Weiser, Gold, & Brown, 1999). Weiser describes his vision of technology as follows:

> *Machines that fit the human environment instead of forcing humans to enter theirs will make using a computer as refreshing as taking a walk in the woods.*
>
> *– Weiser (1991)*

Central to the concept of ubiquitous computing are humans, emphasizing the importance of facilitating human interfaces rather than the prominence of technology itself. Technology should operate seamlessly and imperceptibly in the background, enabling individuals to perform tasks more efficiently and effectively. Weiser extends this idea by likening his vision of computing to the mastery of language by humans, suggesting that once technology becomes sufficiently integrated and intuitive, users will no longer be conscious of its presence (Weiser, 1991).

When Mark Weiser initially proposed his vision of Ubiquitous computing, it was primarily a conceptual framework supported by early technology research studies that hinted at its potential realization. However, in today's context, with the advancement of mobile networks, the internet, and smart home systems, the vision of Ubiquitous Computing has moved significantly closer to becoming a reality.

Although these advancements have brought about necessary technological progress, the actual interactions with smartphones, social media, and the internet have strayed from Weiser's original ubiquitous vision. In contemporary times, technology is more pervasive than ever, often functioning as extensions of human capabilities or integral components of daily activities. Weiser's vision was originally conceived to promote human development through the mastery of technology. However, today it appears that humans may have become increasingly subservient to our own technological creations (Rogers, 2022).

Iterations on the ubiquitous vision

In recent decades, the technology architecture of the Internet of Things (IoT) has seen a meteoric rise in popularity. The concept of IoT involves leveraging the sensory, processing, and connective capabilities of everyday objects within a networked IT infrastructure (Weber & Weber, 2010). While the IoT framework shares many similarities with ubiquitous computing, it differs by focusing more on the functional networking and connectivity of devices, rather than centering on human interactions following Weiser's vision (Ebling, 2016).

Pervasive Computing is a field that continues the original vision of Ubiquitous Computing proposed by Mark Weiser, addressing areas where contemporary technological developments have fallen short. It builds on the realization of these principles through the advanced technologies now available. This approach projects a network of pervasive middleware and networking across devices, as depicted in the framework by Saha et al. (2003) shown in Figure 45. However, the field of Pervasive Computing still faces significant challenges in the effective use of smart spaces, ensuring the invisibility of technology, achieving scalability, and maintaining homogeneity (Saha et al., 2003; Satyanarayanan, 2001).

The value for the bedside nursing practice

Pervasive Computing aligns with human-centered focus of the nurse practice, using technology as invisible enablers of the environment. Nurses expressed in their future perspectives of the generative session their desire for more localized access into IT-networks, such as the Electronic Health Record, Quality Management System (KMS), and digital plannings. Creating a future interventions that disappear in the technological background of the practice. The vision behind Pervasive Computing is a promising prospect for the bedside nursing practice. Therefore, this will be used as the new technology focus for the remainder of the project.

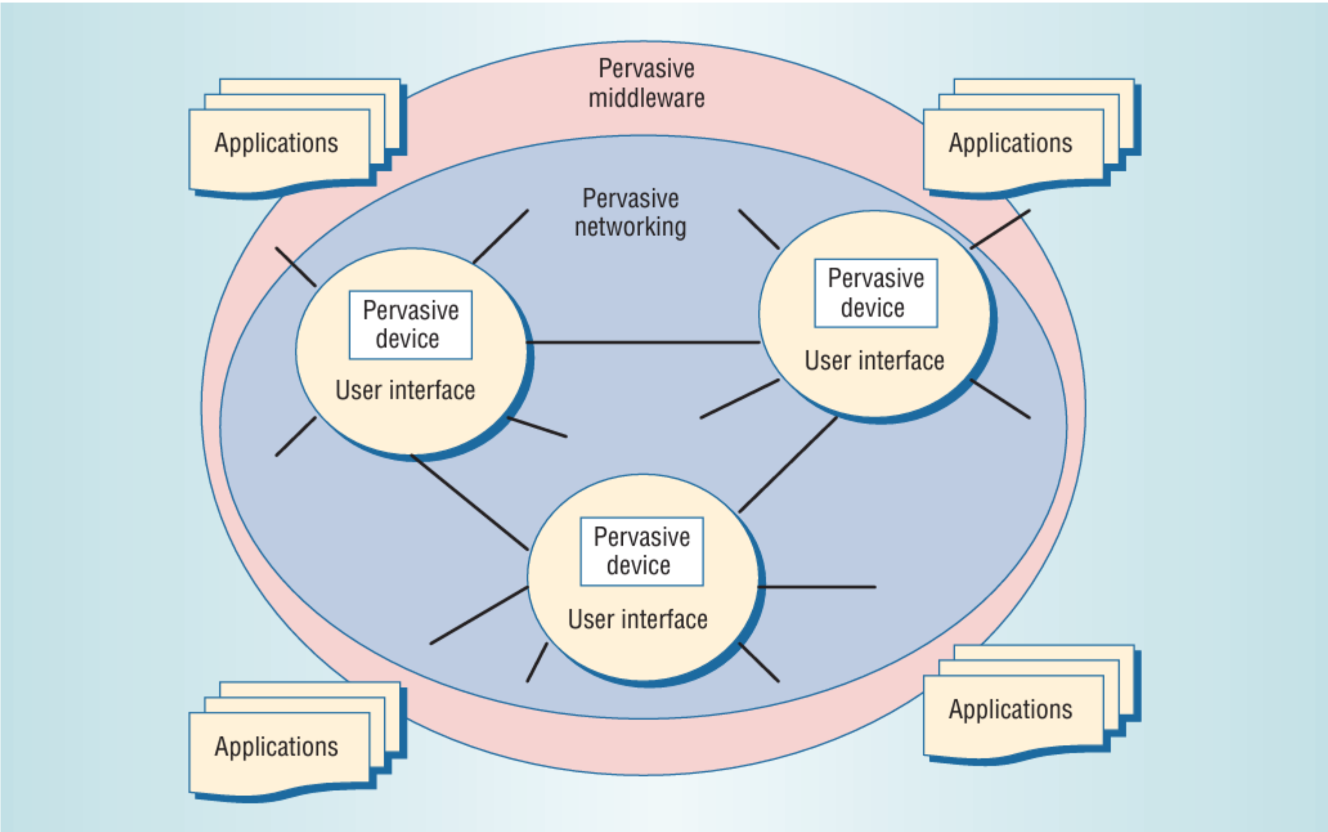


Figure 45: The framework of Pervasive Compution (Saha, Mukherjee & Bandyopadhyay, 2003).

7.4 Design direction

This phase has deepened our understanding of bedside nursing by identifying opportunities across various aspects of the practice, exploring desired future perspectives, and highlighting conflicts between robotics and nursing practice. Through a detailed examination of current challenges and validation of nurses' primary needs, we have pinpointed the cognitive dimension as a key area where technological interventions could significantly enhance bedside practice. Furthermore, insights into the aspirations and ideal scenarios envisioned by nurses indicate that solutions must extend beyond robotics to include diverse technological applications. This section will synthesize these insights to formulate a design direction, which will be developed further in the next phase of the project.

Redefining the technology scope

The development of robotics interventions in the bedside nursing practice currently focuses primarily on automating the delivery and storage of tools and supplies. These areas are indeed actively researched in healthcare, as demonstrated by initiatives like Erasmus MC's robots Temi, Robbie, and the PillPick robot. Given that one of the primary objectives of this research is to generate novel insights and technological interventions, pursuing paths already well-trodden by existing research and design developments would offer limited value, especially without a foundational robotic design to build upon and test.

In contrast, pervasive computing aligns more closely with the future perspectives expressed by nurses during the generative session and the user needs identified in the initial phase. This approach involves seamlessly integrating technology into practice environments and providing easy access to data on demand. Therefore, shifting the technological focus from robotics to pervasive computing seems to be a more logical choice, aligning better with both the research insights and the primary objectives of the project.

Establishing the design goal

Building on this shift in technology focus, the specific research objective for the remainder of this project will be to investigate how technological interventions can be designed to address the unique needs of pediatric nurses at the Children's Thorax Center Ward. Pediatric nurse participants of the generative session highlighted the cognitive dimension as the most demanding aspect of their work. This conclusion is supported by observations of cognitive load during the shadowing activities, representation of cognitive tasks in the desired transformations analysis and by existing research on nurse anxiety.

Furthermore, the positional analysis indicated that recent product de-velopments and healthcare initiatives involving advanced technologies predominantly focus on relational networks and personal patient assistance. While these observations are based on a lim-ited selection of developments and initiatives identified during the project, it is evident that there is a notable absence of advancements aimed at providing support to nurses on an personal and indi-vidual level, specifically within the cognitive dimension.

This apparent dimensional need for cognitive support and alleviation of cognitive load, combined with the established strategic focus, is encapsulated in the following design goal, which design direction is also visually illustrated in Figure 46:

> *Create a personal assistant for pediatric nurses to support them in their cognitive load during the bedside nursing practice at the Children's Thorax Center.*

Figure 46: Visual representation of the design direction, involving a cogntive assistent for nurses during their bedside practice.

Phase 3 | Design

The knowledge generated thus far in this project has remained limited to the theoretical space of bedside nursing practice, offering valuable conclusions at the research level. However, the primary objective is to generate insight and awareness into the actual development of technological interventions that support and enhance the practice. Thus, the critical question arises: how to transition from this intangible theoretical space to the creation of practical interventions that effectively impact actual nursing practice?

This transition begins by understanding the concept of intermediate knowledge, as proposed by Höök and Löwgren (2012). This intermediate-knowledge space, situated between theory and materialized instances in reality, encompasses generative approaches such as knowledge patterns, methods, tools, and concepts. These elements serve as the practical embodiment of theoretical knowledge and are directly involved in the creation and development of design instances. Employing design methodology and activities can thus facilitate the transition towards the tangible materialization of these instances. One such approach, termed 'Research through Design' by Stappers and Giaccardi (2014), uses design activities to generate new stimuli within practices, leading to new research and ultimately contributing to both theoretical and practical knowledge.

In this project, empirical knowledge is gathered from current bedside nursing practice to formulate a desired future perspective, thereby informing the conceptualization of design interventions. Research on the existing practice will guide the development of these interventions. However, employing the Research through Design methodology will also generate new knowledge that contributes to both the understanding of the current practice and the envisioned future perspective. By fostering a continuous interplay between theoretical research and design instances, the goal is to achieve an adaptive approach that aligns research and design developments with practical needs. A generative intermediate-knowledge approach that emphasizes this duality is the concept of 'bridging concepts,' as proposed by Dalsgaard and Dindler (2014).

> *"Bridging concepts are a form of intermediary knowledge distinguished by their ability to facilitate exchange both ways between overarching theory and practice, rather than by being developed from theory or practice or with the specific aim of informing either theory or practice.*
>
> *– Dalsgaard & Dindler (2014)*

Following this definition of bridging concepts, the objective of the final phase of this project is to formulate and develop a bridging concept of a personal cognitive assistant designed to support nurses in their bedside nursing practice.

Chapter 8 | Concept development

The development of a bridging concept begins with the established design goal concluded from the previous phase. Cognitive load can be addressed in multiple ways, and a personal assistant can take many forms. This process requires a creative exploration of design possibilities to determine how a design should function and what it should look like, while being aware of and inspired by existing solutions and product developments related to personal assistance. Furthermore, the design generated in this phase should also reinforce HCI research as a bridging concept, serving as sensitizing material in practice to generate new research insights and knowledge. Therefore, this chapter will focus not only on the design-shaping process from ideation to conceptualization but also on developing an interactive prototype for testing in actual practice for research and design purposes.

8.1 Ideation

The first step in developing a design intervention involves diverging from the established design direction by generating ideas. Known as ideation, this process involves forming and expressing initial design conceptions using generative design techniques. In this research, the aim of ideation is to encourage a broad and diverse array of potential solutions within the framework of creating a personal cognitive assistant for nurses in their bedside practice. One effective design technique that supports this process is Visual Brainstorming, also known as Braindrawing. This design thinking method involves sketching ideas in a space free from constraints, allowing designers to temporarily set aside practical limitations such as feasibility and viability. This freedom fosters the development of innovative, unexpected ideas that might not emerge under typical conditions (Brand, 2019). This section will detail how these specific techniques were applied and discuss the value they produced.

Stimulating and supporting design thinking

Initiating design thinking and coming up with novel design conceptions on the spot can be challenging, often resulting in only a limited number of varied ideas. An effective approach to stimulate and support generative design thinking is the application of the How-Tos method (Van Boeijen et al., 2020). This method involves formulating various How-To statements related to the design space of the established direction. By doing so, designers can concentrate on specific areas within the design space, each prompted by a distinct How-To statement. This process creates a multitude of triggers and starting points for the brainstorming activity, thereby fostering a more expansive and diverse generation of ideas.

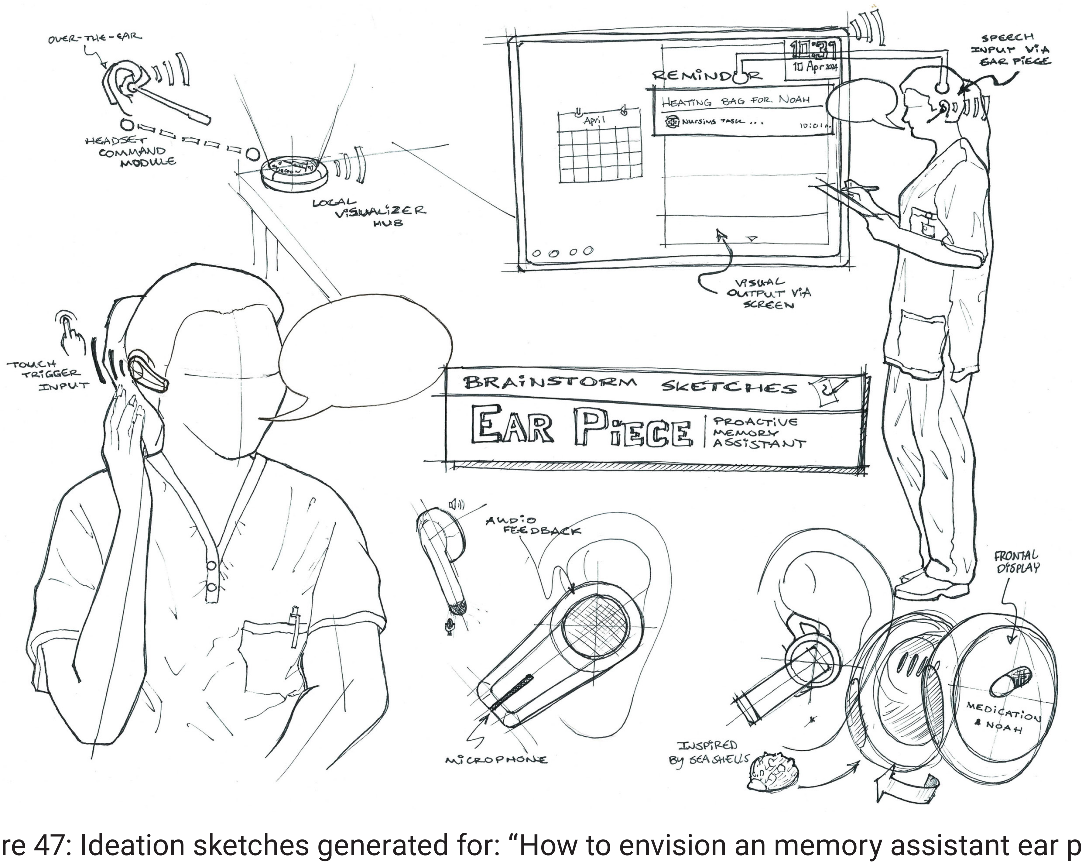


Figure 47: Ideation sketches generated for: “How to envision an memory assistant ear piece?”.

The How-To statements utilized in this ideation phase are primarily centered around the identified primary needs. For example, the statement, “How to easily access a cognitive assistant during bedside nursing?” addresses the previously established need for improved accessibility, as outlined in the design direction of the preceding phase. Meanwhile, the statement, “How to communicate with other colleagues?” addresses the need for enhanced communication among hospital staff. The How-Tos method proved effective in facilitating the brainstorming activity by enabling idea generation through linking and combining the identified elements of the statement clusters.

Visual Brainstorming

The primary principles of the Visual Brainstorming method emphasize the importance of generating a quantity and variety of ideas while postponing judgment and disregarding limitations during the ideation process, as illustrated in Figure 48. Typically, a clearly defined design problem is central to brainstorming sessions to facilitate efficient idea generation and establish the design scope.

However, as indicated by the research conducted thus far, this project adopts a forward-looking approach aimed at enhancing bedside nursing practice and addressing underlying nurses’ needs rather than merely solving existing surface problems within the current practice. Consequently, the design direction for the personal cognitive assistant for nurses serves as the focal point for defining the design scope of the brainstorming process.

Standard brainstorming and brainwriting are effective methods for efficiently articulating abstract thoughts through verbal or textual means. Visual Brainstorming, however, extends these methods by facilitating more conscious elaboration of ideas through visual exploration. For example, describing an initial idea as “a smart pencil that records the writing of the nurse” offers a broad conceptual description and leaves room for various interpretations. The act of drawing a smart pencil forces consideration and definition of its functionality, form, and context of use. The inherent value of personal reflection, discovery, and efficient communication are guiding principles in design Visual Thinking and Visual Doing (Ware, 2008; Brand, 2019).

Ideation results

The Visual Brainstorm resulted in a rich collection of ideas, ranging from smart pens that digitize written notes to earpieces for communicating with a virtual AI assistant, as illustrated in Figure 48. Throughout the exploration, it became clear that cognitive assistance is mainly achieved by providing nurses with “parking spaces” for thoughts, tasks, measurements, and medical assessments while they are actively engaged with their practice. On the other hand, easy access to technological assistance should be provided to the nurse wherever they go, as opposed to the current location-bound technological interventions that require the nurse to move towards technology. This resulted in ideas focused on being worn by the nurse or having the ability to transfer to objects at the nurse’s location.

The realization of pervasive computing with seamless integration of technological access in each practice space is still the desired future perspective. However, the short-term realization and testing of these multifaceted networks of multiple smart devices would be unfeasible for the remaining time of this project. Therefore, the decision was made to pursue the idea of a personal assistant that is worn by the nurse, as it would be the easiest way to ensure accessibility wherever the nurse goes. The position best suited for easy access in the open would be the breast pocket of the nursing uniform, as it is easy to reach without hindering the nurse during practice. This resulted in the idea of a wearable module with voice control, serving as an intercom, gateway, and controller for a virtual assistant.

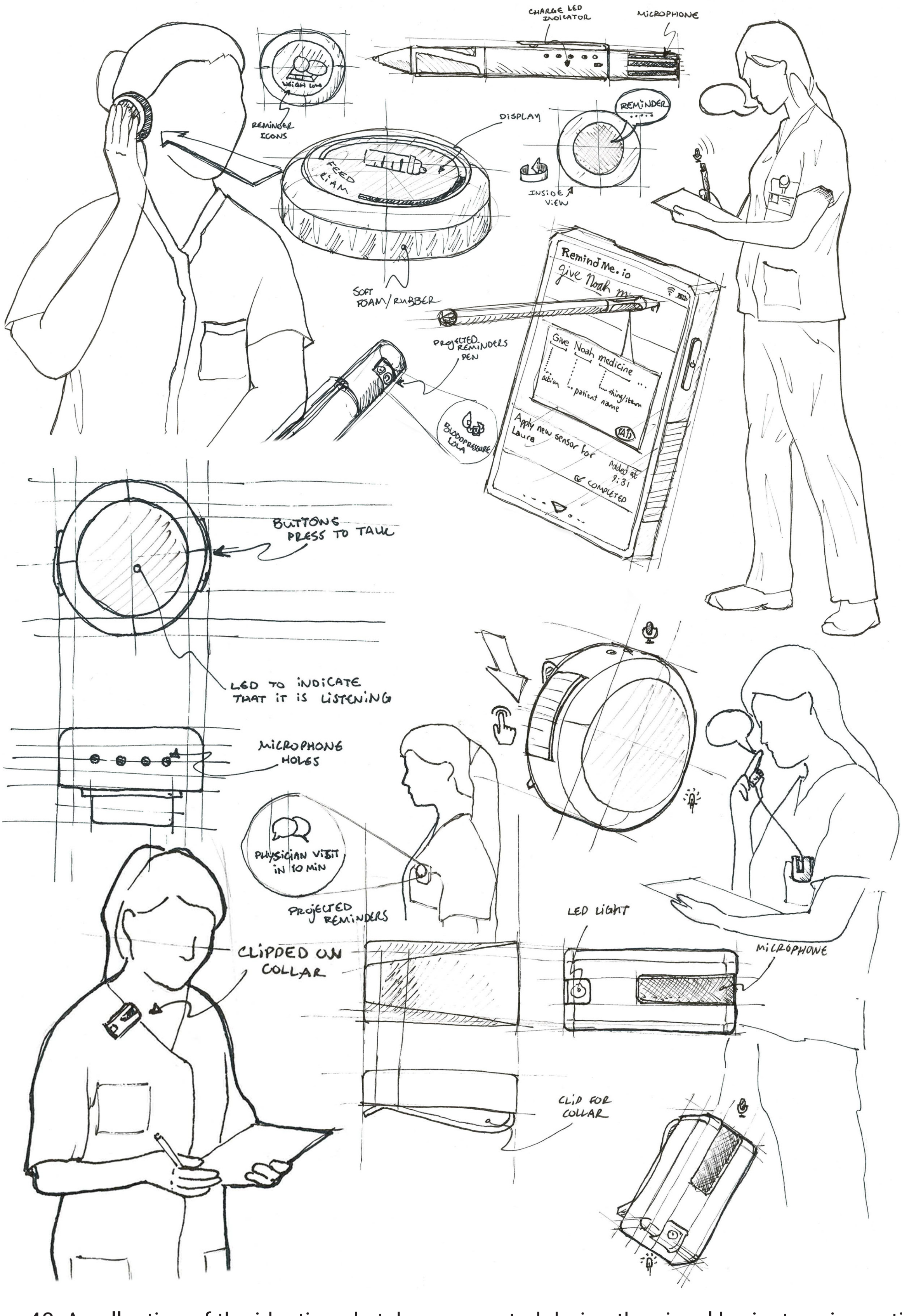


Figure 48: A collection of the ideation sketches generated during the visual brainstorming activity.

8.2 Existing developments of AI-enabled portable devices

With the general concept of a wearable device for virtual AI assistance established, it is useful to explore existing design solutions and related technological advancements. This brief exploration can provide valuable insights to inform the development of the design concept for this project. Interestingly, new AI-enabled wearable technologies were introduced to the consumer market during the course of this project. Two of the most discussed product introductions in 2024 related to AI-enabled wearable technology, the Humane AI Pin and the Rabbit R1, will be examined in this section, as their market introductions received overwhelmingly negative reviews.

Humane AI Pin

The Human AI pin, launched in April 2024, is the first device of its kind available to consumers, as depicted in Figure 49. Developed by Humane, a company founded in 2018 by former Apple designers, the AI pin is a multi-modal wearable device designed to provide users with AI assistance through cloud connectivity. The device attaches to clothing via a magnetic backpiece, which also serves as a battery, enabling continuous wireless charging. A distinctive feature of the pin is its newly developed palm projection interface, which operates through hand gestures. Additionally, the pin features a front-facing touch panel for functions such as activating the speech interpreter and navigating the interface, an integrated camera for capturing photos and videos, and voice control via AI speech recognition (Humane, 2024).

The launch and reception of the Humane AI pin have been rocky, to say the least. Many well-known tech review companies and social influencers have given the new product poor ratings due to its high price point, the required paid subscription model for connectivity, and its subpar operational capabilities (Pierce, 2024; Brownlee, 2024). Notable issues with the device include the impractical use of its projection interface, compounded by inaccurate sensor readings and AI performance; slow connectivity and instabilities that hinder AI feedback; and its general failure to differentiate itself sufficiently from a smartphone to justify its value for daily use. While the AI pin represents a bold attempt to realize futuristic AI assistance, it falls short in terms of optimization and actual usability.

Rabbit R1

A few months after the release of the Humane AI pin, Rabbit Incorporated introduced their first pocket AI device. Marketed as a more affordable alternative to other portable AI-enabled devices, the R1 features a multi-touch screen and is primarily operated via voice control and an analog scroll wheel, as depicted in Figure 50. The design philosophy behind the R1 is to provide users with streamlined access to AI services with minimal interaction, thereby enhancing convenience for on-the-go use. However, similar to the Humane AI Pin, the Rabbit R1 received an overwhelming negative reception from established reviewers. Criticisms focused on unreliable AI features, cumbersome interface interactions, and slow response speeds (Chokkattu, 2024; Spoonauer, 2024). While the Humane AI Pin at least was praised for its Apple-like build quality and innovative features, the R1 is criticized for cutting corners to achieve a lower purchase price.

General takeaway for this project

Recent developments in AI-enabled devices reveal that portable AI technology is still in its early stages, with current products showing notable shortcomings. To distinguish and justify itself from existing solutions, this technology needs further optimization for effective, efficient, and accurate AI responses, as well as streamlined interaction designs for operation. These aspects are also crucial points of focus in the development of this project’s idea. Nonetheless, the appearance of these gadgets in the consumer market are indicative that portable AI is gradually being integrating into daily life.

Figure 49: The Humane AI Pin (Humane, 2024).

Figure 50: The Rabbit R1 Pocket Companion (Rabbit Incorporated, 2024).

8.3 Cognitive Companion

The subsequent design step involves refining the idea into a well-defined bridging concept that not only integrates the identified research insights but also generates new ones. The established need for cognitive support has been linked to AI-enabled personal assistants within the context of pervasive computing in bedside nursing practice. Recent consumer products of such AI-enabled technology have exhibited primary shortcomings, including a lack of practicality and poor interaction design. Therefore, these critical aspects will be central to the conceptualization process of a wearable cognitive assistant for nurses. This section will discuss the considerations and design decisions involved in shaping the bridging concept of the Cognitive Companion (Coco).

Inception of the Concept

As established throughout the research analyses so far, supporting nurses in managing their cognitive load is the primary purpose of the concept that has to be developed. AI-enabled technology, in the form of a personal assistant, can provide that additional support through collaborative partnership and by extending human capabilities through technology. Combining these fundamental aspects into a design concept resulted in the creation of the Cognitive Companion, or Coco for short. Beyond its role in cognitive support and being a working companion, the name “Coco” was inspired by the idea of a parrot and was found to be both friendly and catchy.

The general aesthetic and embodiment of the concept were briefly explored through sketching, but since this is only a bridging concept and an intermediate design, it was not extensively researched. An overall round shape with curved notches was chosen, as it fits the friendly appearance of the name, the pediatric ward context, and the intended role as a companion. The microphone is located on top to place it as close to the mouth of the user. The front of the device consists of the top notch with an RGB LED in the top notch for colored light notifications, the bottom notch as speaker opening, and a touch panel in between for manual operation. Furthermore, the blue ring around the device is designed as a knob to adjust the volume of Coco’s notification sounds and spoken messages, as depicted in Figure 51.

Memory Assistance

Based on the desired transformations and primary user needs identified from earlier research activities, the concept should support nurses in managing their cognitive load during bedside nursing. This can be achieved by providing nurses with “mental parking spaces,” as mentioned in the ideation phase. These parking spaces should be designed to accommodate reminders for tasks, measurement values, medical assessments, and other general information that may arise during practice. By doing so, nurses can concentrate on current tasks and functions without being concerned about remembering things for later.

The reminders are saved in the virtual memory of Coco and will also be accessible through a Coco Chat Log on the medical smartphone. This feature originated from nurses expressing their preference for visual feedback during the generative sessions. A visual chat log, which includes not only all the reminders but also other commands, can provide nurses with an overview of completed tasks and information useful for medical reporting. Therefore, this simple connectivity with the medical smartphone—via a possible Coco app or existing software integrations—could provide valuable interaction insights for further design research.

Next, the cognitive assistant should proactively intervene to remind nurses of their saved content. This is a challenging task, as it has been established that nurses already experience overstimulation due to the abundance of alarms and notifications from existing devices. Therefore, the assistant must be able to interpret the correct situation for intervention to be effective. Perceptual recognition through camera detection is also not ideal, given the sensitive nature of the hospital setting and the technical challenges posed by dynamic environmental factors, such as lighting and numerous objects.

Thus, location tracking might be one of the most suitable solutions for proactive sensing. By placing a small sensor at the entrance to each room in the ward, the cognitive assistant can determine the live location of its wearer. When it detects a transition from one room to another, it can identify a suitable moment for intervention based on the type of transition.

Figure 51: Visual render of the Coco concept with its main features.

This approach is still theoretical and could change in the near future as more connected and intelligent devices are integrated into nursing practice in hospitals. However, for this current bridging concept, this approach, along with time-bound reminders similar to standard alarms and notifications on smartphones, will be defined as the sensing capability for the cognitive assistant.

Interpersonal Communication

It has also become very clear that nurses desire better means of communication during their practice. Nurses currently have medical smartphones to call colleagues and a Telecare system with assistance buttons to notify others when they require assistance. However, these interventions are rarely used, as Telecare buttons are mainly for urgent situations. Furthermore, calling is found to be either too disruptive during workflow or too burdensome when navigating the contact list and finding the right number to call. Pediatric nurses often encounter nonurgent and minor occurrences where they need to communicate with a colleague, such as asking what the exact time of a physician's visit is or if a patient has already had their nutrition administered.

Therefore, easy-to-access interpersonal communication with adaptive notifications is integrated into the concept design. Nurses can simply command Coco to call or message someone by stating their name. Then, Coco will either directly contact the colleague's Coco in the case of a call or wait for an opportune moment, like the reminders, to point out the message.

Robotic Delivery

It was also observed and stated by nursing during the research activities that their work consists of walking up and down between rooms to get tools and supplies. While this predominantly embodies the physical load of bedside nursing work, it also affects the cognitive side of the practice, as it disrupts mental focus on tasks and requires additional mental capacity, such as for locating and remembering items.

With the earlier discussed developments of transportation robots for delivery, it is a logical assumption that in the future this will be more commonly integrated across all the hospital wards. In such a future network of robotic delivery, Coco can be a mediator for the nurse to operate such robots and process delivery requests. Therefore, this potential functionality will be integrated into the current bridging concept of Coco. Nurses can ask Coco to get certain tools and supplies for them, which then will be processed and communicated to storage and delivery robots.

Integration with Medical Databases

Data security and other regulatory contingencies are already sensitive and challenging aspects for existing electronic health records and data networks in hospitals. Secure integration of new technology, such as a personal assistant into these networks, would require extensive costs for development and testing to prevent data breaches and violations of privacy policies.

It remains to be seen whether integrating a cognitive assistant into medical databases is truly necessary to support nurses in their cognitive tasks. It may be that an AI-enabled personal assistant for cognitive tasks at the bedside, interpersonal communication, and potential robot delivery could be sufficient to justify the use of such an intervention. Therefore, this integration with medical data is deliberately left out of the current bridging concept to determine if it is actually necessary for the value proposition of a cognitive assistant used by nurses.

8.4 Developing a Pretotype

Design concepts can be realized for testing through various methods, ranging from Minimum Viable Products (MVPs), which include only essential features to demonstrate interactivity, to advanced prototypes that closely simulate the final product. Although developing an advanced prototype of the Cognitive Companion (Coco) would provide precise user feedback and testing results, such an undertaking would require substantial investment in time and resources, which is not feasible within the scope of this graduation project. Moreover, proceeding directly from a theoretical concept to an advanced prototype poses risks, as the true impact on practice remains uncertain. Therefore, the decision has been made to create a simple interactive model representative of the Coco concept, as introducing such a model in practice would already yield valuable new insights into its effects.

Methodology for the pretotype activity

While traditional prototyping is an experimental process aimed at refining and evaluating designs, pretotyping focuses on validating whether the direction of the idea is correct. Conceived by Google Engineering Director Alberto Savoia, pretotyping aims to prevent fixation on refinement through design development by addressing the validity of the core concept before making further investments (Savoia, 2022; Connor, 2020).

> *The goal of pretotyping is to help you make sure that you are building The Right It before you build It right.*
>
> *– Savoia (n.d.)*

This emphasis on validating the design concept prior to testing it for refinement and development is consistent with the current stage of development in this project. However, it is important to note that the primary aim of the testing activity is to generate knowledge based on initial interactions with and introduction of the pretotype in practice. While validating the Coco concept is useful, it is the understanding of the underlying reasons and effects in practice that provides valuable insights for further research and intervention development. Therefore, the pretotype of Coco utilized in the upcoming activity will primarily be an experimental device for generating new insights, rather than focusing on evaluating the design.

Furthermore, introducing the pretotype into actual bedside nursing practice provides invaluable insights into interactions and their effects in practice. The contextual inquiry method applied during the job shadowing activities at the start of this project was found to be very effective in gaining a deeper understanding of the practice. Applying this technique again, but this time while using the pretotype in practice, would allow the researcher to interact and reflect with the nurse on the interactions with Coco and uncover the thoughts and reasoning behind them. Accordingly, the following research objective is constructed for the pretotype activity:

> *The objective of this final exploratory activity is to acquire new insights for the development of a personal cognitive assistant for nurses by introducing the Coco pretotype into actual bedside nursing practice.*

Designing the pretotype

The pretotype must be simple enough to be developed quickly while being sufficiently defined in its interaction and embodiment to serve as a sensitizing trigger for nurses to reflect on during use. Therefore, the decision was made to design the pretotype with some reactive elements, such as light and chat feedback, to support the simulation of interactions.Autonomous voice control

Figure 52: Visual representing the pretotype setup.

through speech recognition was deemed too complicated for this initial model, therefore, this functionality is simulated through remote operation by the researcher. This means that the researcher role-plays as Coco's intelligence by interpreting commands and providing feedback, as illustrated in Figure 52. For example, when the user says Coco's wake word and voice command, the researcher remotely activates a blue light on top of the device to indicate that it is listening and then listens to the command being spoken by the user. Regarding proactive intervention behavior, the researcher needs to keep track of the user's location and time during use. However, this should be manageable since the researcher is already shadowing the user during the activity for contextual inquiry.

Furthermore, when the user physically initiates the listening functionality through touch, the pretotype must react with the blue light autonomously. Integrating this functionality into the pretotype model adds perceived autonomy and reactivity. Incorporating a direct light reaction from the model when touched would not be difficult. On the other hand, the blue ring serving as a volume knob does not need to be operational, as the researcher will be simulating audio feedback and observing the participant closely. Still, a dummy knob is included to inform users of this functionality and allow for the interaction.

Finally, visual feedback interactions are simulated through the Google Chat application on a smartphone. A private conversation is created and opened on a smartphone, which will be given to the user, representing the Coco Chat Log on their medical smartphone.
The researcher has the same private conversation open on a tablet and adds reminders and other information through speech commands by placing messages in the Chat Log. Additional feedback messages, such as arrival notifications for certain delivery tasks or text messages from colleagues, are also included in this Chat Log.

Software and Hardware Components

The prototype model was custom-designed in SolidWorks based on the envisioned Coco design concept, with modifications made to accommodate Grove module placement and the Fused Deposition Modeling (FDM) 3D-printing manufacturing method. All parts, except for the electrical components, were 3D-printed using Fiberlogy Easy PLA in white and navy blue on an Ender 3 Pro V2, as illustrated in Figure 53.

The Arduino prototyping platform with Grove components was chosen for this pretotype because it offers the easiest way to program and implement the necessary interactivity, given

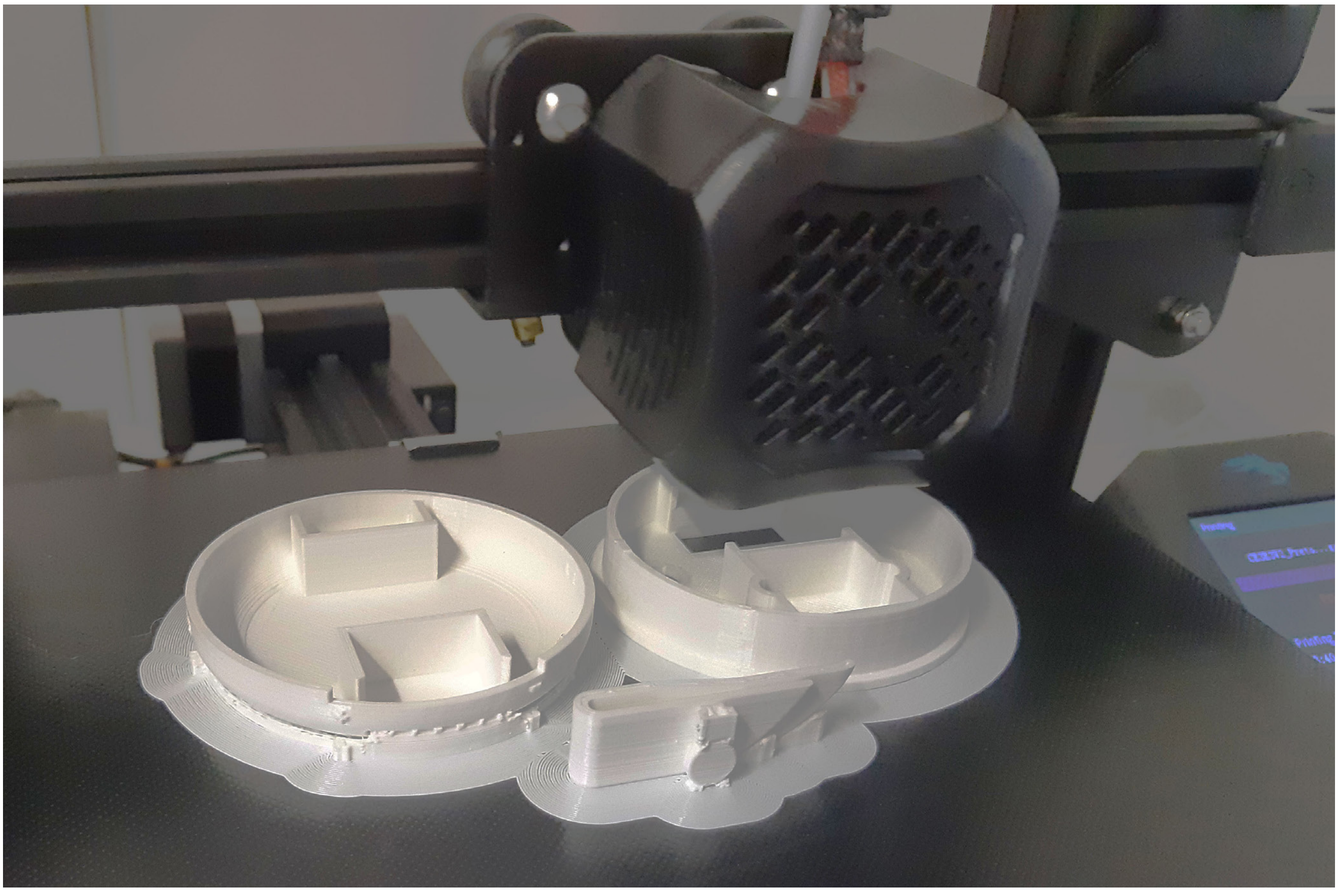


Figure 53: 3D-Printing of the pretotype model.

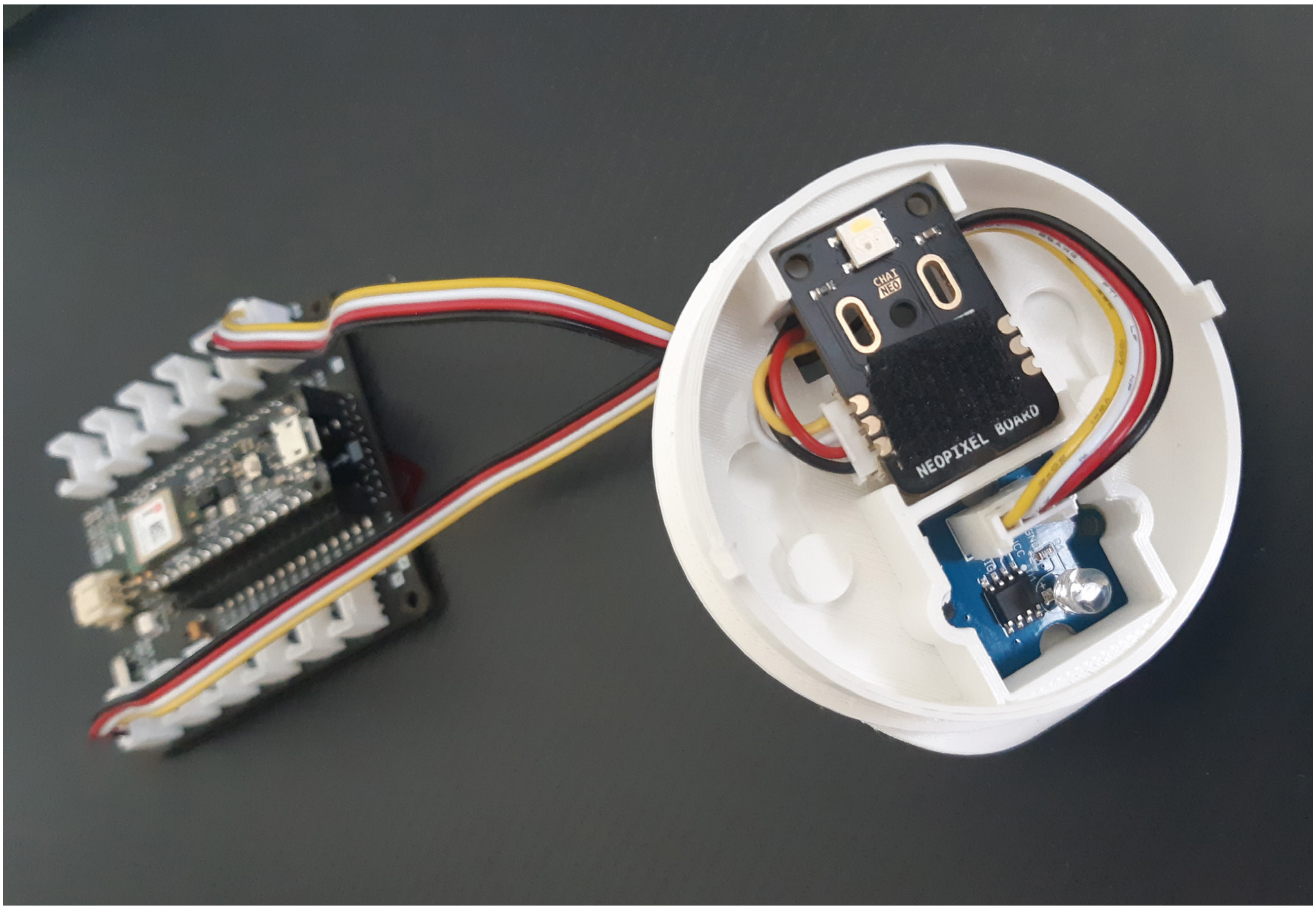


Figure 54: Internal components of the Coco pretotype.

the designer's existing experience with Arduino programming. The pretotype model requires remote and wireless operation; therefore, the Arduino Nano 33 BLE Sense was selected as the microcontroller board due to its Bluetooth capability. The remote operation via Bluetooth was achieved using the LightBlue Development Tool application by PunchThrough on an iPad, and by sending specific case values for certain pretotype reactions to the Arduino board. Furthermore, the Nano board was connected to a Grove Connector Board developed by ID StudioLab, which facilitates easy connections with Grove component modules, as shown in Figure 54. The complete assembly of the microcontroller board and Grove connector was powered by a Denver PBA-4001 4000mAh power bank and protected in a 3D-printed case, allowing it to be easily placed in the user's pocket.

For the touch activation of Coco's listening feature, a Grove button module was initially tested at the front of the device. However, the shape and size of this module proved difficult to integrate into the 3D-printed model and also deviated from the intended interaction of the concept. Therefore, the decision was made to use a light sensor in the bottom notch of the pretotype to simulate the touch function, as no speaker was included in the pretotype. When the user placed their hand on the bottom notch, they obstructed the light reaching the light sensor, and the touch interaction was detected. Furthermore, the only output component used in the prototype model was a ChaiNEO Chainable RGB/W LED Grove module, which simulated the different colored light feedback. The complete finished pretotype is shown in Figure 55.

Figure 55: Picture of the finished Coco pretotype powered a the powerbank.

Chapter 9 | Research through design

The research conducted thus far in this project has focused on examining the current state of bedside nursing practice, providing valuable insights into the practice, as well as the challenges and needs experienced by nurses. However, when proposing potential solutions and desired changes, the process inherently involves hypothesizing an envisioned future based on the existing practice. For instance, the introduction of a new intervention into practice will impact the various practice dimensions, such as individual perception, behavior, relationships, and interactions. Consequently, engaging in design activities, such as prototype testing or design simulations, is crucial as they establish new practice dynamics that can be further investigated through research. This approach, which utilizes design actions to generate new knowledge, is a core principle of the Research through Design (RtD) methodology and will be integral to the pretotype exploration activity discussed in this chapter.

9.1 Pretotype explorations in practice

Research and design are fundamentally related as expressions of human learning and the creation of novelty. While research primarily concentrates on generating new knowledge through systematic investigation of reality, design focuses on the development of artifacts into reality. As previously introduced, the Research through Design (RtD) methodology employs design activities to create novel research manifestations for further analysis (Stappers & Giaccardi, 2014). This approach is particularly valuable for the current developmental phase, where insights derived from research must be validated by introducing a design intervention into practice and examining its effects. This section will elaborate on this exploration activity of the Cognitive Companion (Coco) pretotype model in the actual bedside nursing practice at the Children's Thorax Center.

Activity setup

The pretotype exploration activity was conducted with three pediatric nurses during their working shifts at the Children's Thorax Center ward at Erasmus MC Sophia, as depicted in Figure 56. The nurses were recruited through the contact person at the ward and were provided with detailed information about the activity via email prior to participation. Of the three participants, two had previously been involved in earlier research activities related to this project. Nonetheless, this was also their first encounter with the design concept of Coco. The researcher wore a nursing uniform and proper identification, following shadowing and intern policy at the Erasmus MC.

Figure 56: Picture of the pretotype explorations at the Sophia Children's Hospital.

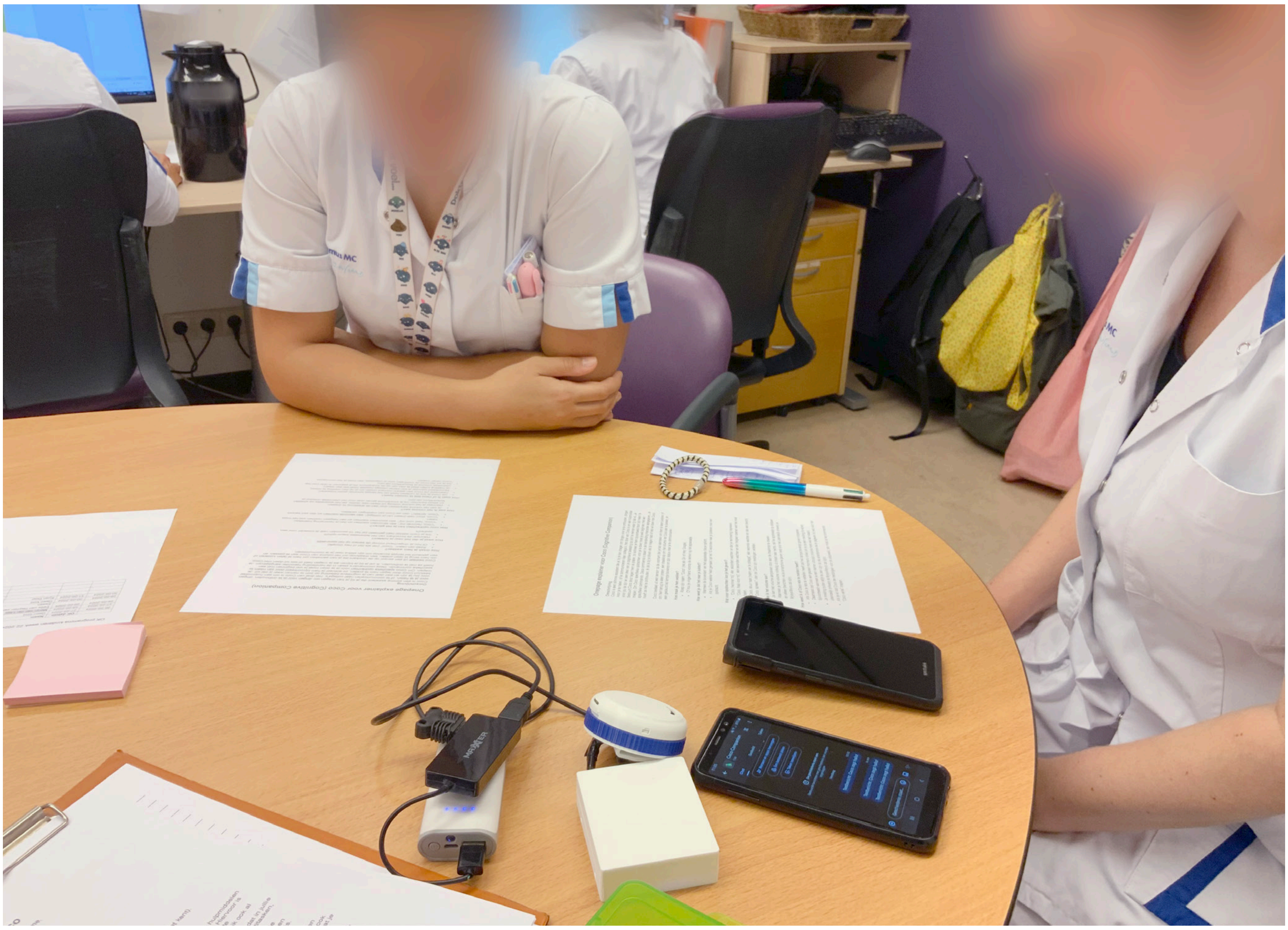


Figure 57: The introduction for participants at the nursing post.

The entire activity was audio-recorded to capture as much data as possible, as the pretotype required remote control by the researcher, making note-taking challenging. This was achieved by attaching a Bluetooth lavalier microphone to the participant's collar and using an iPad with a recording application.

Introduction for participants

Each prototype exploration research begins at the nursing post, where the researcher introduces both the activity and the pretotype to the participant, as illustrated in Figure 57. Initially, the researcher provides an overview of the project, runs through the activity plan, and outlines the participant's roles and expected contributions. Subsequently, the participant is given time to explore the pretotype, supported by a one-page explainer on the Coco concept and pretotype. This preliminary familiarization helps the participant understand the basic functionalities and envisioned uses of the pretotype. Additionally, conducting this initial familiarization is essential to minimize disruption to the participant's work, as the activity occurs during a real nursing shift. Once the participant is adequately acquainted with the pretotype and indicates readiness, the actual pretotype use in practice starts.

Pretotype use in practice

During the pretotype's use in practice, the researcher shadows the participants as they operate the pretotype and conduct the contextual inquiry. The researcher remotely activates the blue light on the pretotype when the nurse speaks the wake word, indicating that Coco is listening. Physical activation by touch is fully automated and requires no additional action from the researcher. However, the researcher does enter the voice commands given by the participant into the Coco Chat Log via the Google Chat application to simulate visual feedback and track the commands for later research analysis. Furthermore, the researcher activates a specific blinking colored light response depending on the notification from Coco: green for reminders, yellow for completed deliveries, and pink for messages and calls.

Contextual inquiry is used throughout the course of the pretotype activity. The researcher observes user interactions with the prototype and interferes by asking the participant for their thoughts and reasoning. This way deeper knowledge levels containing thoughts, feelings and desires can be extracted through reflection during use and captured as much as possible on the audio recordings.

The goal of the activity is to generate comprehensive insights into the desired development and use of Coco. Consequently, improvisation of functions and other design modifications during the activity is encouraged. This approach was frequently implemented, with nurses proposing additional functions and features that were tested through the pretotype's interactivity. For instance, a nurse suggested integrating a calculation function into Coco. During the activity, the researcher simulated this function by responding to the query, “Calculate for me: 39 times 4,” with the answer “156,” which was subsequently recorded in the Coco Chat Log, as depicted in Figure 58 below.

Figure 58: A nurse looking through the Coco Chat Log.

Figure 59: Coco pretotype during nursing activities.

The duration of the pretotype activity varied between 20 and 60 minutes, depending on the working shift of the nurse participants. The first two activities were held during calm shifts when the nurses ran out of nursing tasks to do, resulting in the pretotype activity ending relatively quickly. In contrast, the third activity took place during a much busier and more chaotic shift, leading to significantly longer use of the pretotype across various nursing tasks and situations.

Reflective Interview

An interview was conducted after the pretotype activity to reflect on user experiences and elaborate on participant remarks. The researcher began by asking general questions about participants' overall impressions of the activity and Coco, followed by questions about both the predetermined and suggested functionalities of Coco. General topics and themes, such as overstimulation and privacy, were also discussed in detail.

The pretotype explorations were highly successful, generating a wealth of data from audio recordings, observations, and interviews. However, some limitations, such as the lack of a speaker for sound, prevented participants from experiencing certain interactions. This limitation led to feedback based more on assumptions rather than actual experience. Nevertheless, the exploratory use of the pretotype provided invaluable insights for further defining and developing the Coco concept and HCI research.

Figure 60: Coco as part of the nursing gear, with the bluetooth microfoon for audio recording.

9.2 Data Analysis Process

The pretotype explorations in practice generated a wealth of data, which requires thorough analysis to extract valuable insights and knowledge crucial for further research and design development. The first step in data processing involved transcribing the audio recordings of the pretotype activity and reflective interviews. This process allowed for the extraction of statements as direct references to participant feedback. Subsequently, statements containing valuable information were derived from the transcriptions and categorized to identify recurring themes and patterns. This section will detail the process and reasoning behind the data analysis applied to the pretotype explorations in practice.

Transcribing the audio recordings

The audio recordings from the pretotype activity and reflective interviews were transcribed into text format to anonymize sensitive information for storage and facilitate ease of use for further data processing. The recordings were transcribed using Atlas.ti software into a Microsoft Word document for further layout editing. The type of transcription used in this software is Verbatim, meaning that the transcription closely adheres to the audio recording, even capturing pauses and sighs (Semantix, 2024). This way, the full extent of participants' expressions is captured, which might contain hints of their feelings and attitudes.

Next, the participant statements in the text transcriptions were analyzed for valuable information regarding research or design development. These statements were collected on Post-it notes in a Miro virtual workspace and edited to correct grammatical errors and capture the essence of each statement. This way, the statements fit the formal tone of this thesis and can be used as references.

Categorization of the gathered data

The Post-it notes in Miro were grouped based on shared themes and topics. Each group was given a title to assign meaning for easy reference and further categorization. Subsequently, these groups were categorized based on their relevance to design functionality, output, embodiment, operation, value proposition, and developmental challenges. This categorization of statement groups represents the valuable information for the Coco concept. Further interpretation by the researcher of these statements, along with observations made during practice and data from Coco chat logs, will form the actionable insights for design development in the upcoming subchapter.

Results of the data analysis

The data analysis and categorization revealed distinct clusters related to desired changes in the design concept, insights into existing features, and new challenges discovered during practical usage. Overall, nurses were generally positive about Coco's accessibility and cognitive support capabilities, appreciating how these features could enhance their practice. However, they clearly emphasized the need for integration with medical databases for effective data management. Without this connectivity, nurses do not see sufficient added value in adopting such an additional intervention in their practice.

Furthermore, voice control in practice remain to be a challenging operational use to be effective. Nurses stated the usage of Coco during night shifts when patients and parents are asleep. In this case, audio based operation and feedback are questionable due to its practical implications regarding volume detection and muting interactions.

The following chapters will provide a detailed discussion and reflection on the results of this analysis.

9.3 Design Development Insights

The exploration activity of the pretotype in practice provided valuable insights into the viability and functionality of the Coco design concept. Interaction with the pretotype demonstrated clear uses of its established functionalities, including memory assistance, interpersonal communication, and potential delivery of tools and supplies. Feedback from the nurse participants highlighted the importance of network integration for bedside data processing and access. Furthermore, suggestions for additional functionalities, operational methods and data feedback of the design concept will be discussed, supported by statements from the nurses during the exploration activities and reflective interviews. Ultimately, this section will examine the insights related to the design of Coco and the conclusions that can be drawn for the further development of the concept.

Memory assistance

During the pretotype explorations in practice, all the nurses effectively utilized the reminder functions. The memory assistance employed in these activities primarily involved the recording of vital parameters and nutritional intake values, as well as serving as reminders for pending tasks during their work shift. Concerning this functionality, the primary value of the Coco concept resides in its capacity to offer a more accessible and efficient alternative to the currently used note sheets. Its ease of use during bedside practice is underscored by its hands-free speech control feature, as illustrated by the following statement from a participant:

> *When weighing a child on a scale, they might fall off, so I don't write it down immediately as I have my hands full. I usually remember it and write it down afterward. Hence, I would definitely ask Coco to remember it for me, even with things like checkups. I would also pass these values on to Coco directly.*
>
> *– Nurse participant 2*

However, the nurse participants also expressed reservations about Coco's value solely as a memory assistant. While the use of note sheets may appear somewhat unprofessional and improvised, they are a simple, cost-effective, and efficient means for nurses to manage reminders and patient information during their practice.

Consequently, the complexities associated with integrating and adapting a device like Coco must extend beyond merely replacing a note sheet, as highlighted by the following statements from the nurses:

> *In Coco's current state, I would still use the note sheet. However, if additional tools and support are added to the rooms, we might no longer need the note sheet. However, this won't be achievable by only adding the Coco device.*
>
> *– Nurse participant 1*

> *I don't see the value in changing my routines and adding a new device unless it offers more than just saving reminders. I want it to call people, send messages, bring things to me, and integrate with Hix. If it can do all this, it would be worth using. Otherwise, my note sheet suffices for reminders."*
>
> *– Nurse participant 3*

Bedside access to databases

Current registration tasks extend throughout the course of the nursing shift, beginning at the moment of medical assessment, which predominantly occurs at the patient's bedside. The actual registration of data input and reporting are frequently deferred until the nurse has completed all immediate care duties, at which point they can attend to these tasks at a desktop. This behavior necessitates that nurses memorize completed tasks, measurements, observations, and medical assessments throughout the duration of their practice, contributing significantly to their cognitive load.

> *"Today, I only have two patients; therefore, I am able to quickly complete my care tasks and report everything at the computer. However, on busier days, I don't have time for that. On such days, Coco would be very useful for working more efficiently."*
>
> *– Nurse participant 2*

Interestingly, nurses are provided with Computer On Wheels (COW) and apps on their medical smartphones to access the databases wherever they are. However, they report not using these tools due to their inconvenient and inefficient use during bedside practice. Accessing a computer or smartphone screen diverts attention from patient care and involves a slow process of navigating through databases, which disrupts the flow of bedside practice.

> *"I would use Coco if it were connected to something, such as your smartphone or preferably directly to HiX, as this would significantly reduce the registration load. However, without this connection, I don't see the benefit of using it, since I can write things down just as easily on a piece of paper."*
>
> *– Nurse participant 1*

As exemplified by the statement of nurse participant 1, all nurses clearly expressed the necessity of integrating the Coco concept into IT networks to provide direct connectivity between databases for data input and information retrieval, as well as other devices for locating them and synchronizing data. Connectivity is therefore one of the predominant features that should be incorporated into the Coco concept in further design development.

Interpersonal Communication

Interpersonal communication is once again highlighted during the prototype exploration activity in practice. This is remarkable, given that nurses are already provided with calling functions on their medical smartphones and assistance buttons via the Telecare System. Nonetheless, nurses cite the inconvenient use of these interventions as the primary reason for their infrequent use. Calls are typically made from the nursing post to contact medical personnel in other hospital de-partments. However, within the ward and among nurses, calls are considered too much of a hassle, as they require actively searching through a list of contacts during bedside care and are also too disruptive for the recipient. On the other hand, telecare assistance buttons installed in each patient room are only used by nurses in critical emergencies or by patients who mistakenly believe they are light switches. There is currently no dedicated intervention for minor communication requests that are of low priority but still need to be addressed at any location and at any time. The following two commands are examples of how Coco was addressed during the activity to aid in such minor communication needs:

> *"Coco ask my nursing buddy: What time should the medication be administered to the patient in room A?*
>
> *– Nurse participant 1*

> *"Coco send my nursing buddy a message, that 10 minutes is fine.*
>
> *– Nurse participant 2*

Coco was also used to call the cleaning service and a nursing colleague, as it appeared to facilitate easy and spontaneous calling requests during practice. Nevertheless, the primary distinctive advantage that Coco offers over the medical smartphone and Telecare System lies in its enhanced accessibility and the potential for advanced functionality, such as assigning different levels of urgency to communication requests. While text messages are received with uniform notifications, calls with a ringtone, and Telecare buttons with an alarm, Coco enables nurses to convey a message with a specified level of urgency through a single command. The receiver's Coco could then respond appropriately based on the assigned urgency level. This is therefore where the main value proposition of the Coco concept should therefore focus on addressing this problem and behavior, that ultimately leads to the cognitive load.

Additional functionalities

Nurses also expressed a desire for additional functionalities to be integrated into Coco. Specifically, two nurses highlighted the need for calculation assistance during the practice. Nurses frequently perform calculations for medication dosing and the proper settings of medical devices. Although basic mental arithmetic skills are expected form a trained nurse, the stress and workload experienced during practice can increase the likelihood of errors. Therefore, incorporating a simple, easily accessible, and fast calculation function could be a valuable addition to Coco.

> *I would also like to have a calculation tool in Coco! That I can say: "Coco calculate for me, this or that." Because now we have to calculate it in our heads, which sometimes could lead to mistakes.*
>
> *– Nurse participant 1*

Furthermore, a simple timer function would also be a valuable addition to Coco. Nurses frequently encounter tasks that require reassessment or modifications after a specified period, in accordance with protocols or prescriptions. For example, Coco was used to set a timer for the removal of an ointment, as illustrated by the following command statement:

> *Coco set a timer for an hour: Remove the Rapydan.*
>
> *– Nurse participant 2*

One nurse participant also noted that language barriers are increasingly common in contemporary nursing practice. Given that Coco is already designed to utilize voice control through speech recognition, integrating an automatic language translation functionality would be a natural and valuable enhancement to its capabilities.

Different nurse participants also indicated a preference for Coco to include a feature for quickly verifying medication administration. Currently, nurses are required to have their medication administration verified by a qualified colleague as part of safety protocols. They expressed frustration with the time wasted on locating a computer to complete the administration themselves and searching the ward to find a qualified colleague for verification.

> *Is it also possible that Coco can validate my second check? Because now I have to find another colleague to verify the administration for me.*
>
> *– Nurse participant 1*

Medication administration is a critical task with a high risk of harm to patients if doses are administered incorrectly. The requirement for a second validation of medication administration serves as a logical precautionary measure. Consequently, replacing human validation with AI necessitates careful consideration and thorough assessment. Given these concerns, it is unlikely that Coco could incorporate this feature in the early stages of its development as a personal assistant.

Finally, connected to this functionality is the reoccurring need to solve time wasted on searching artifacts and people. Like previously identified as desired transformations in Phase 1, locating devices and supplies at the ward are again highlighted as desired added functionality to Coco. The automation or guidance in locating supplies in storage rooms already has been part of the future perspective discussed in Chapter 6.1. However, during the prototype exploration activity, nurses have expressed again their desire to implement a tracking function in Coco.

> *"Can I also ask Coco: Where can I find a thermometer right now? Because now I have to search or ask someone, which can be very frustrating."*
>
> *– Nurse participant 3*

Implementing extensive tracking for the majority of devices and tools within the ward would indeed be challenging. However, as medical devices increasingly advance in connectivity and sensing capabilities, integrating such a feature into Coco could become feasible in the future. Locating personnel, on the other hand, may present a more realistic prospect, particularly if Coco is adopted by all nurses. Locational awareness has already been identified as a valuable aspect of the Coco concept, as discussed in Chapter 8.3, Cognitive Companion. With this awareness, it could be feasible for Coco to track the locations of colleagues through the Coco devices they carry.

Operational control and feedback

The speech recognition was found to be an effective method for hands-free operation of Coco, as previously mentioned and exemplified by participant statements. The nurses highlighted challenges regarding the potential disruptiveness of speaking out loud in the presence of sleeping patients and parents, especially during night shifts. Additionally, speaking out loud sensitive medical or private information might pose challenges for speech operation. Nurses suggested whispering to Coco or using alternative means of operation in such situations. These considerations will be incorporated into the design proposal for further development.

The communication means for device feedback was also found to be a challenging aspect. The colored light notification signals from the integrated RGB LED in the pretotype had mixed effectiveness among the participants. Some participants found it to be a clear signal and noticed it, while others did not see the light at all due to the device's low placement, which was outside their field of view when focusing on tasks beyond the device, as depicted in Figure 61. Overall, notification sounds are preferred, provided they are not too disruptive or overstimulating to the environment.

> *"Yes, I would love to have notification sounds! We were doing something, and I didn't notice the light at all. I don't pay attention to it.*
>
> *– Nurse participant 2*

> *"Some small sounds, such as a confirmation beep, would be acceptable. However, I am hesitant about adding more sounds because I already experience a lot of overstimulation from noise.*
>
> *– Nurse participant 1*

Figure 61: Some nurse participants did not notice the light notifications as it is out of their periphery when focused on nursing tasks.

Furthermore, nurses are also doubtful about the speaking-back function of Coco. They clearly emphasize that they do not want Coco to automatically starts speaking, as it disrupts user conversations, sleeping patients and lacks overall control by the nurse. This feedback functionality should therefore be solely activated by for example an user command or button press.

> *I think I would prefer a visual representation on my Myco because it is the only way I can keep the information to myself and view it at a single glance. That is why I prefer seeing it over hearing it out loud.*
>
> *– Nurse participant 3*

On the other hand, some nurses also highlighted the benefits of visual information representation on their medical smartphones, as exemplified by the statement above. Therefore, the integration of visual feedback should be considered in the further development of the Coco concept.

Main takeaway for design development

The Coco concept was generally well-received by the participants, with nurses demonstrating clear enthusiasm for the potential benefits and opportunities that a cognitive assistant could provide. All participants actively used Coco in their work practice and were inspired by its interactions to engage in generative design thinking, leading to the addition of more desired functionalities and interactions to the intervention.

> *It was a lot of fun and I am definitely really enthusiastic about the whole idea of Coco.*
>
> *– Nurse participant 1*

> *I think that Coco supports us very well! Considering all the things I have said to Coco, which I no longer have to take extra time to enter into the computer myself or remember by writing things down, it saves me a lot of effort! Ultimately, this also means more time for us nurses to provide quality care.*
>
> *– Nurse participant 3*

However, when questioned about the potential integration of Coco into their daily work routines, the nurses strongly emphasized the importance for added connectivity with medical databases and other devices. Rather than functioning as a standalone cognitive assistant, the Coco concept should serve as an easily accessible personal gateway to connective data for nurses, regardless of their location. It should facilitate direct data input and information retrieval from medical databases, support interpersonal communication, and offer additional functionalities beneficial for bedside practice. Ultimately, the primary value proposition of Coco lies in its personal accessibility, control of data management, and supportive features for cognitive tasks at the bedside practice.

9.4 HCI Related Findings

The introduction of the Coco prototype as an intervention in the nursing practice led to notable shifts in practice dynamics. Its presence changed how nurses typically conducted their task routines and influenced interactions between nurses and parents. While nurses primarily viewed and utilized Coco as a tool, preliminary signs indicate the potential for developing collaborative relationships between humans and artificial agents with proper integration and extended use. This section will explore the significant observations and insights related to human-computer interactions observed during the pretotype explorations in practice, linking these insights to the theoretical framework of Objects with Intent (Rozendaal, 2019).

Framing of Coco

The Objects with Intent (OwI) framework proposed by Rozendaal (2019) explores three distinct facets to comprehend how OwIs function as collaborative partners. The first facet, Framing, examines how individuals within a practice interpret the object and how the object, in turn, influences their perspectives. This facet emphasizes the mutual shaping of meaning between the object and its users, highlighting the bidirectional relationship that can transform both human understanding and object functionality (Rozendaal et al., 2019).

During the pretotype exploration activity, Coco was predominantly framed as a tool rather than as an entity, based on the observed behaviors and expressions of people in the practice. The nurse participants primarily referred to Coco as an "it" and demonstrated a clear, one-directional interaction hierarchy indicative of tool use, such as through authoritative commands aimed at executing actions rather than engaging in interpersonal reasoning. Furthermore, when asked about their perception of Coco, two out of three participants explicitly stated:

> *I would not characterize it as a strong bond at this stage. I perceive it more as a tool, similar to my HiX database.*
>
> *– Nurse participant 1*

> *Yes, nothing more than a tool.*
>
> *– Nurse participant 2*

However, on rare occasions later in the activity, some nurse participants began referring to Coco as an entity, even asking the researcher whether Coco is a 'he' or 'she.' This is noteworthy as it may be indicative of initial framing of Coco as an entity and suggest the potential development of relationships with a personal assistant like Coco in this practice. The third nurse participant also expressed the potential development of relationship with Coco, by the following statement during the interview:

> *I have to admit that Coco feels more intimate than a standard device. Because it goes wherever I go, I can talk to it, and it can help me and provide support. It feels more like a collaborative relationship with a personal assistant.*
>
> *– Nurse participant 3*

These preliminary indications of potential collaborative relationships between the nurses and Coco align with the conceptualization of OwIs as collaborative partners. Although the pretotype has demonstrated certain interactive facets that suggest expressive potential, limitations in autonomy and practical functionality constrain a more profound analysis and understanding of the envisioned concept in practice (Rozendaal et al., 2021). These initial findings necessitate further research and practical realization of the concept, which will be explored in greater detail in the upcoming chapters.

Embedding of Coco into the practice

The primary desire of Coco's connectivity with databases and other devices within the practice underscores the importance of its integration and coordination through established IT networks, as detailed in the previous subchapter on design development insights. The speech interactions with Coco appear to align well with accessibility needs during bedside nursing, offering hands-free and direct control of data and communication. However, the use of speech operation presents challenges, such as the sensitivity of spoken content (e.g., medical and private information) and the potential for introducing noise into the practice environment. Consequently, solutions such as incorporating whisper functions or alternative methods of operation, such as text-based AI detection, will be examined further in subsequent chapters of the design proposal and opportunities for future research.

Furthermore, the nurse participants appear to perform more tasks at the bedside with Coco in close proximity. The spatial constraints associated with certain nursing tasks, such as data input, information retrieval, interpersonal communication, and tool localization, were mitigated by bringing these tasks to the nurse's location rather than requiring the nurse to go to the location of the technological means. On the other hand, Coco's actual intervention capabilities remained limited and undefined in the pretotype, requiring the researcher to manually decide when to intervene for reminders based on their own judgment rather than Coco's technological sensing and computing. This limitation was anticipated and deliberately ignored to facilitate the exploration of the pretotype's use in actual practice, as discussed in Chapter 9.1, "Activity Approach."

However, deeper understanding of accommodating intervention opportunities for reminders and communicative notifications necessitates further research with a more integrated and accurate representation of the concept, operated from the technological perspective of Coco's embodiment.

Transformational effects in Practice

The pretotype of Coco in bedside nursing practice had observable influences on both the dynamics of the practice and the people involved. Nursing colleagues quickly noticed the addition of Coco to the participants' uniforms and curiously inquired about its purpose and functionality (Figure 62). Initially, parents were intrigued by the nurses' interactions with the device but understood its purpose and benefits once the nurses explained Coco to them.
The introduction of new technology into the nursing practice appears to startle people, as it contrasts with the focus on human interaction and empathetic care in daily nursing practice. Coco became the topic of conversation between parents and nurses during activities, with parents mainly expressing skepticism about the replacement of human nurses by technology.

However, once Coco was explained by the nurse participant and identified by others through its use in action as more of a tool than an autonomous artificial entity, the general perception became more trusting and open, largely due to the sense of human control it conveyed. Parents began making lighthearted and friendly jokes about the possible uses of Coco, such as bringing them a robotic massage chair, while understanding the benefits of the intervention for the nurses' work. The nurse participants also started off a bit hesitant about Coco's uses and interactions but quickly became more familiar with it and regularly used the pretotype in their practice.

Nurses appeared to rely less on their note sheets when using Coco for reminders and cognitive tasks at the bedside. Nursing tasks appeared to be more efficient with the speech functionality of Coco, allowing the nurse to operate it wherever and whenever needed. However, it is important to emphasize that the functionalities of the pretotype were simulated and are not actually operational. Consequently, nurses still had to perform their usual nursing tasks, such as manually inputting data at a desktop and walking to retrieve items they had requested from Coco's delivery function.

These limitations made it challenging to determine true transformative changes in the practice and assess long-term impacts. Further research involving actual controlled operations and a comprehensive representation of the practice with the Coco concept is necessary to accurately evaluate the transformational aspect of Coco as an Owl.

Figure 62: Due to its size and wiring, the Coco pretotype is quite striking.

Chapter 10 | Final design proposal

This design proposal represents the culmination of extensive research, analysis, and design development conducted throughout the project's lifecycle. By integrating theoretical insights with practical considerations, it aims to deliver an innovative yet feasible perspective on the future of bedside nursing practice, addressing the identified challenges and opportunities within the HCI research domain. The proposal begins with a final revision of the Cognitive Companion (Coco) concept design, drawing on insights gathered from the pretotype explorations. This section establishes the core principles and rationale underpinning Coco's value proposition for integration into bedside nursing practice, providing a comprehensive understanding of its potential impact. Following this, the proposal highlights the most significant challenges facing the realization of the Coco concept and identifies areas for further research and design development. Finally, the chapter concludes with a roadmap for the continued development and implementation of the Coco design concept, outlining the necessary research steps and resources required to transition from proposal to realization.

10.1 Revising the Cognitive Companion Concept

The pretotype explorations in practice have yielded valuable insights for improving the Cognitive Companion (Coco) design concept. The use of the Coco pretotype in actual practice has clearly demonstrated its potential to support nurses and enhance their bedside nursing practice. Coco enables nurses to focus more on providing quality care to patients at the bedside by alleviating cognitive load from interactions that are misaligned with the bedside practice and tasks that are restricted by current technological interventions. However, to achieve this, the Coco concept requires seamless integration into medical databases and the overall user experience. This final rendition of the Coco concept will highlight the value of properly integrating persuasive computing into the bedside nursing practice and elaborate on how this can be realized based on the research findings throughout this project.

Establishing the value proposition

Bedside nursing practice in this pediatric ward demands high-intensity cognitive engagement from nurses, who must multitask by focusing on carefully executing current tasks, continuously applying medical assessments for patients, planning ahead, and coordinating shared care with parents and colleagues. Current technological interventions, however, even worsen this cognitive load by forcing nurses to remember medical assessments and values in addition to their multitasking demands during a shift. Although nurses are provided with bedside access for data management through interventions such as medical smartphones or Computers On Wheels (COWs), these solutions often lack practicality and are considered too cumbersome for use at the bedside.

Therefore, the main value proposition of the Coco concept is to provide nurses with a personal intervention that ensures easy and efficient data accessibility wherever they go, using simple and unobtrusive interactions designed to align with the nursing practice at bedside while maintaining control over their work. In other words, Coco brings and adapts technology interactions to the nurse, rather than requiring the nurse to adapt to the technology interactions.

Coco in a pervasive computing ecosystem

Embedding Coco into networks of medical databases and connected devices is essential for its value proposition. Nurses require unconstrained access to data management and communication, aligned with the specific nursing interactions at their location. This need for seamless integration and accessibility in every environment aligns with the principles of pervasive computing, as discussed earlier in Chapter 7.3. Therefore, rather than being a personal assistant embodied in a wearable device, Coco should be a virtual AI assistant within a pervasive computing ecosystem consisting of a large network of smart devices across the ward. By following this design concept, smart devices connected to the ecosystem can serve as the senses for the Coco assistant, with some also providing a temporary embodiment of Coco for localized user access. The wearable device, as presented in the bridging concept and prototype, should not be the assistant itself but should serve as a personal touchpoint for nurses, always available for easy access to and operation of the virtual Coco AI assistant during practice.

Furthermore, given the current limitations in computing power and connectivity, it is impossible to run AI machine learning models, let alone deep learning models, on the small wearable devices necessary for the envisioned assistance, as presented in the bridging concept and prototype. The logical solution currently employed in AI-enabled devices is to perform the computing on centralized servers and transfer data between the device and the server via network connections. However, as seen with the recently introduced AI-enabled assistants on the consumer market, connectivity speeds and stability, server processing speed, and AI prediction accuracy remain technological challenges that must be addressed to make this solution effective and worthwhile.

Reiterating the Coco wearable device

A final iteration of the Coco wearable device design was made and incorporated into a tangible model to capture insights from the pretotype explorations, as illustrated in Figure 63. It is important to highlight that this proposed design of the Coco wearable is just another iteration intended for further testing as part of the ongoing development and design refinement.

Nurses predominantly used the physical touch activation for voice control, as they found it to be a more consciously controlled interaction for Coco's listening activation. Therefore, this alternative feature to the hands-free wake word activation must definitely be retained. However, during pretotype usage, a nurse accidentally kept bumping and activating Coco during bedside nursing tasks because the device protruded too much from the body. Nurses also expressed concerns about eavesdropping and recording unintended private conversations. Accidental activation of the listening feature is, therefore, a sensitive and critical aspect that must be carefully considered in design iterations. Consequently, the size and thickness of the device should be reduced to prevent obstruction of movement. The frontal touch activation in the concept design has been moved to the side of the device to prevent accidental activations. The overall shape of the design has also been changed to rectangular to assess how this impacts interactions and framing of the device.

Furthermore, the slide clip design for attaching the device to the breast pocket was found to be too vulnerable during use, with a risk of dropping the device. Spring-loaded clips, which are used with the newer Ascom Myco medical smartphone models, are a preferred and more secure attachment method according to nurses. Sound notifications have also been added, as they were preferred over the difficult-to-notice colored light feedback observed during practice. Nurses have emphasized that these notifications need to be loud enough to be noticed, but not so disruptive that they add noise to the environment and cause overstimulation. Therefore, the design of notification sounds need to be tested iteratively in actual practice.

Additionally, nurses highlighted the need for silent operation of the device, especially during night shifts when patients or parents are sleeping. With the existing envisioned features of AI speech feedback and the addition of sound notifications, a mute button or switch should be added to ensure a silent mode on the device. Furthermore, a touch panel can be added to the front of the device, inspired by the Humane AI Pin, to allow silent touch gesture operation as an alternative to voice control.

Another interesting feature to explore is supporting whispering as a form of voice control. Silently talking to the device could work, but a magnetic reattachment system between the clip and the main device could also provide users with the option to take the device closer to their mouth for quieter and more private voice control.

Ultimately, these design changes are some final projections for this project based on findings from the pretotype explorations in practice. They require further testing and comparison with future prototypes to be validated and refined.

Figure 63: Reiteration model of the Coco wearable device.

10.2 Research and design challenges

The reimagined concept of Coco within a pervasive computing network represents the desired future perspective for bedside nursing practice based on the research findings of this project. However, realizing this vision in actual practice poses several challenges that must be addressed through further research and design development. As demonstrated by existing AI-enabled technologies in the consumer market, fast response times, stable connectivity, and accurate AI interpretation are still critical aspects of technological feasibility that require ongoing development. Additionally, speech recognition and audio feedback must be tested in actual practice to uncover unforeseen consequences and effects that this research project has not yet explored. Finally, the connectivity of data networks and accessibility across multiple devices adds complexity in ensuring the protection of sensitive medical information.

Technology adaptations in practice

The proposed designs for Coco are still in the early stages of development and require further iterative conceptualization and refinement. Design aspects such as functionalities, interactions, and user-friendliness need to be specifically prototyped and tested in actual nursing practice to be validated. The achievements of this project are reflected in the research and design insights that will guide further development or other future projects for technology integration into healthcare settings. Identifying the correct design focus and envisioning future perspectives based on a deeper understanding of the selected practice can be time-consuming and require considerable patience. However, getting this initial scoping and alignment right is invaluable for designing technology interventions that genuinely support users and improve practice.

The main challenge in further developing the Coco concept for practical adaptation is ensuring its distinctive added value for users in practice. As nurses clearly expressed during the pretotype exploration, a device like Coco must offer more than just minor benefits to their practice. Adopting new interventions in healthcare requires significant investment in time and effort, and it could potentially affect the quality of care if not approached properly. Since nurses have a strong responsibility for patient well-being, they are very particular and critical about the tools and methods used in nursing practice. Although nurses are provided with medical smartphones featuring numerous applications, they often avoid using them at the bedside if they do not seamlessly align with their practice. This critical importance of seamless integration and alignment with specific practices is also a high-priority challenge for not only further development of the Coco concept, but for all future technological applications in healthcare settings.

Pervasive computing in healthcare

The other primary challenge resulting from this project is the realization of pervasive computing in healthcare. Pervasive computing seems to be a suitable technology concept aligned with the needs for interaction and technological support identified in bedside nursing practice at this specific ward. The principles of invisible, seamless access and technological enablement with a human-centered focus naturally fit healthcare practices with similar human core values. The future perspectives of nursing practice described by nurses during the generative session share a lot of similarities with typical visions of pervasive computing, describing technology interventions integrated into different practice environments for easy access to connected medical data and communication.

However, the pervasive computing concept is nothing new to healthcare research, as its user-centered principle alignment with healthcare practices has been identified and studied by

Figure 64: The design of Coco has to be iteratively optimized and tested in practice.

researchers for years (Rastegari et al., 2011; Arnrich, 2010; Tentori, 2012). So why has it not been integrated and developed into healthcare practices yet?

The true realization of pervasive computing has mostly been a future dream, held back by technological limitations, as it requires complex connectivity, coordination, and synchronization of invisibly integrated technology in spaces (Saha et al., 2003; Satyanarayanan, 2001). However, with technological developments like the Internet of Things, AI, and quantum computing on the horizon, what was once a distant and unrealistic dream might become realistically feasible in the coming decades.

This project initially set out with a technological focus on robotics, but through extensive practical research, pervasive computing emerged as the best technology concept suited to the practice. However, this project only managed to scrape the tip of the pervasive computing iceberg. Therefore, it is highly recommended to further research the design challenges of integrating and realizing pervasive computing in hospital nursing practices.

Privacy and data protection

The predominant challenge in integrating AI-enabled and connected technology in healthcare practices concerns privacy and data protection. Increasing the number of devices connected to medical databases and networks also raises the risk of hacking and data leaks. While the added complexity of connectivity in technology applications is desired by nurses and designers, it causes headaches for IT engineers and safety specialists.

Safety and privacy should always be prioritized in healthcare developments, as they are inherent to the quality of care provided by medical professionals and the hospital. Therefore, while the future perspective of pervasive computing in bedside nursing practices might be hopeful, it also poses significant challenges in maintaining data security and the privacy of sensitive information that must be addressed. In other words, privacy and data protection are priorities not only reserved for certain professions but are inherent to the desirability, feasibility, and viability of research and design development for technological solutions in healthcare

Transdisciplinary challenges

Ultimately, all the aforementioned challenges come down to transdisciplinary collaboration in the research and design development of technology interventions in healthcare practices. Interventions in practice must be iteratively researched and developed, which is only possible through transdisciplinary interactions in actual practice.

The healthcare experts, consisting of nurses, nursing researchers, and other medical professionals, have the knowledge and experience in the most crucial element of innovation development: the actual practice. Their challenge is to involve and guide experts from other disciplines into their field and practices. Meanwhile, for experts from other disciplines, the challenge is to engage with the actual practice of intervention and gain an understanding of the people and practices involved. The nurses and nursing researchers in this project have been instrumental in providing the design graduate researcher with access and guidance to gain a deeper understanding of essential knowledge for designing. This required openness and engagement from both sides to result in effective knowledge exchange and generate new knowledge together.

Next, the realization of pervasive computing is only possible with extensive transdisciplinary collaboration, as it involves a complex network of people and technology that need to be connected, coordinated, and practical in use. This challenging prospect of pervasive computing for transdisciplinary collaboration has not been explored in this project. Therefore, a definitive answer on how to do this effectively has not been found yet and requires further research to be effectively answered.

Finally, privacy and data protection are a joint endeavor involving design considerations, communication, and research. Medical experts have the knowledge and experience necessary for handling privacy and data in practice. Therefore, they are key players in establishing what data connectivity is necessary to support practice and what privacy considerations are appropriate in practical situations. Technology experts have the power to find technical and design solutions that better protect privacy and data, influencing what needs to be protected in the first place. Meanwhile, organizational experts have knowledge and power over regulatory systems and policy management, understanding to what degree privacy and data protection should be maintained, while also providing regulatory frameworks for innovation and overall improvement.

Figure 65: Privacy and data security will be one of the predominant challenges for voice controlled AI.

10.3 Development roadmap

A roadmap serves as a strategic framework for navigating the complex landscape of identified challenges and ensuring the seamless integration of technology interventions into the bedside nursing practice. This section outlines the roadmap for advancing the Cognitive Companion (Coco) concept, detailing the approach to research and design that will drive future technology projects in this healthcare context, as depicted in Figure 66. It addresses key issues such as interoperability, user adoption, and feature integration based on the learning of the research through design conducted in this project. By establishing clear milestones, the roadmap will guide iterative refinement, rigorous testing, and the deployment of technology into daily practice. Additionally, it aims to provide insights and value for broader HCI and transdisciplinary research, emphasizing the importance of involving people and practices in the development process to benefit all healthcare stakeholders.

Practice development

One of the main takeaways from this Research-through-Design project is that the development of technological interventions should start with a strong focus on specific healthcare practices. The bedside nursing practice is facing nurse shortages alongside the ever-increasing demands for quality care due to a rising population. Technological interventions have already revolutionized current nursing practices, with present-day nurses adapting to and operating advanced medical devices, databases, and new policies. This trend of technological advancement and practice evolution will continue, bringing increasing complexity to maintaining an improved care system.

While technology can provide automation of repetitive and redundant tasks, more accurate AI risk assessments, and nursing support at the bedside, the degree of seamless integration into specific practices will determine whether such technological innovations will complicate the nurses' work and add to their load or actually relieve them and allow for better care. Therefore, it is crucial to be aware of practice development and its effects on the actual people involved. Focusing solely on technological application might cause more or different harm than the overall benefits.

Technology development

The healthcare application of technological innovation generally appears to be following societal acceptance. AI-enabled assistants have already become common appliances in homes (e.g., Amazon Alexa and Google Home) and on computers and smartphones (e.g., Siri and Cortana) since their introduction in the early 2000s. However, actual applications in healthcare have mostly remained in the research phase. Technological innovations take time to be implemented into healthcare practices, requiring extensive risk assessments, optimization, and public acceptance in order to be used in such sensitive and strict settings.
It is essential to start examining current technological developments that might hold value for a sustainable healthcare future. Recent advancements in more advanced deep neural network AI tools, such as ChatGPT, show that AI-enabled technology is gaining momentum in public interest and is starting to become more influential in daily human life, beyond mere gadgets and handy tools limited to certain markets. They will become an integral part of daily human practices, including healthcare settings. Quantum computing will open the doors to another technological revolution for AI and large-scale data networks, placing the responsibility on experts in all fields to collaboratively guide them into actually desired and beneficial solutions. It is no longer a question of "if," but rather "when" pervasive computing will become the actual practice in nursing.

Research development

As stated, technological developments will have an increasing cross-disciplinary influence, requiring more transdisciplinary collaboration for research and development in healthcare integration. Research must be conducted into all dimensions of innovation development and application, from data security of future technology networks to human-computer interactions in actual practice. However, these research endeavors are correlated with each other, requiring transdisciplinary communication, coordination, and collaboration. Transdisciplinary research methods, like the Research-through-Design methodology applied during this project, need to become more commonplace in order to intertwine academic and practical data, information, knowledge, and ultimately, wisdom.

Regarding the field of design, from which this thesis originates, further research into human-computer interactions will become more prominent with the growing advancement of complex technology. Theoretical frameworks and concepts, such as Object with Intent and Pervasive Computing, should be guiding principles for developing technological innovations that are sufficiently integrated into practice. The actual feasibility of implementing the Coco concept in the healthcare setting needs further research, as it would be impossible to conclude this in the early stages. While this project might not have achieved the iterative design development envisioned at its launch, future projects must follow an iterative development process to formulate interventions and achieve optimization. Ultimately, the principles and methodological approaches for problem-solving, analysis, and creative development of design are invaluable for transdisciplinary engagement in 'design thinking' and 'design doing.'

Design development

The bridging concept of Coco presented in this project is one of many design interpretations that can be derived from research in bedside nursing practice. Other intervention manifestations, such as integrations into existing objects and devices, might be even more suitable for the envisioned future perspective. Furthermore, it is important to emphasize Coco as a manifestation of a potentially desired intervention and as a tool to stimulate further research. The exact design embodiment, including features, components, and the use of specific materials, must be determined through further definition of the actual intervention.

The AI-enabled wearable module in the Coco concept represents a more feasible transitional intervention toward a future of full pervasive computing, with seamless and invisible integration into practice environments. Therefore, the Coco wearable might become redundant over time as advancements in practice overtake its initial value proposition. This will happen when everyday objects in the practice environment, such as patient beds, spatial lighting, nurse uniforms, and possibly even the flooring in ward rooms, become integrated with sensory and data-accessible capabilities in pervasive computing networks.

Completely overhauling existing objects and networks in practice to achieve the vision and value of pervasive computing is impossible. It requires developmental advancements and processes of learning from individual interventions to realize advanced network integrations. Otherwise, it would be like completing a puzzle without considering each piece thoroughly. Moreover, the people in practice require time and space to adapt to changes to maintain the quality of care and well-being before even improving it. Ultimately, making small, focused developments of individual interventions and networks is crucial to achieving a pervasive computing future.

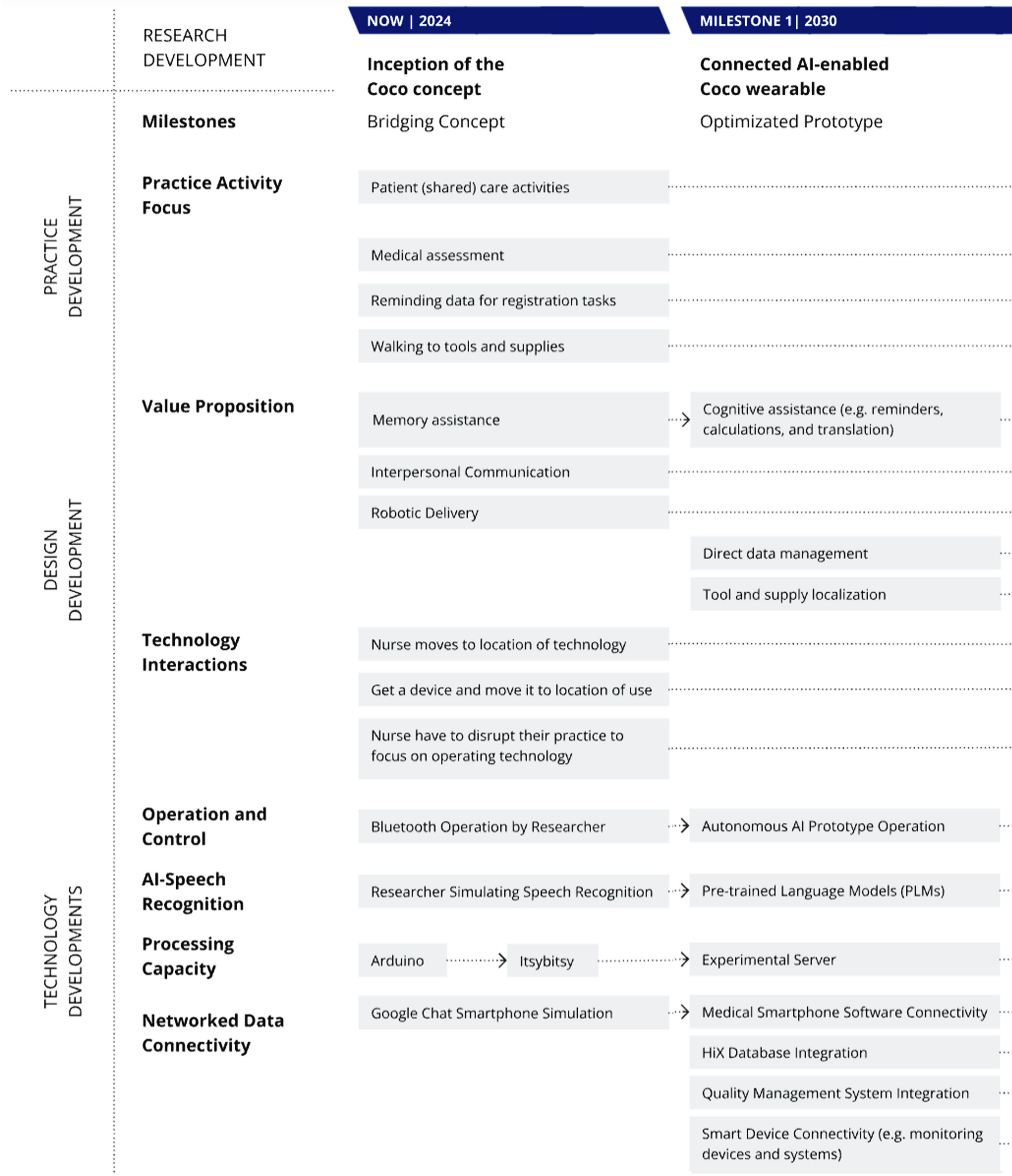


Figure 66: Roadmap

MILESTONE 2 | 2035

First Integration of Coco in practice

Market Introduction

MILESTONE 3 | 2040

Pervasive Computing Nursing Environments

Desired Future Perspective

Milestone 2 - 2035	Milestone 3 - 2040
	Predominant focus of nurse on patient (shared) care activities
AI-assisted medical assessment support	AI-assisted medical assessment verification
Registration Tasks Done at Bedside	Verify Automated Data Registration
Robots get tools and supplies for nurses	
	The Coco wearable is decommissioned as its value becomes redundant.
	Coco truly becomes a virtual assistant for all sorts of control and support.
	A cohesive network of smart objects and technology integration into spaces, allows for a diverse set of ways for operation.
Mobile access to computing and data	Ubiquitous access to computing and data
Devices are brought or located for the nurse	Technology is invisibly integrated in spaces
Nurse can quickly and easily operate technology during practice	Seamless operation of technology
Autonomous Virtual AI Operation	Autonomous Ubiquitous AI Operation
Large Language Models (LLMs)	
Centralized Hospital Servers	High Speed Quantum Mainframe
	Universally connected technology integrated in objects, spaces and databases for continuous data transfer

Project Conclusions

This project has studied the challenges involved in the research and design development of technology applications for the bedside nursing practice. By conducting several research activities using the Research through Design methodology, it gathers valuable insights for HCI research, transdisciplinary challenges, and design development toward a future perspective of pervasive computing.

From an HCI research perspective, this project concludes that future technological developments for bedside nursing should predominantly focus on human interactions and care as fundamental aspects that must be safeguarded. The cognitive load experienced by pediatric nurses is found to be primarily caused by the misalignment of technological situatedness and interactions. This misalignment forces nurses to postpone registration tasks and find workaround alternatives to adapt to practice, resulting in them having to remember values, assessments, and other reminders. Technological interventions should be designed to abide by practice-specific interactions and user needs, situating and adapting the interventions to the nurse, rather than forcing the nurse to conform their practice to technological interactions. Ultimately, the goal is to reserve and support the nurse's time, focus, and energy for providing actual patient care.

The technological vision adhering to these principles and resulting from this research study is a desired future perspective of pervasive computing for bedside nursing practice. The principles of pervasive computing, emphasizing human-centeredness and the ubiquitous accessibility of computational data and control, are a natural fit for the identified primary user needs and a desired future perspective on the practice of nurses. Therefore, the realization of this technological concept should be pursued through further research and design development. One proposed bridging concept to aid these developments is an AI-enabled wearable named the Cognitive Companion (Coco). This proposed concept serves as a stimulative and sensitizing intervention in practice, enabling the necessary research knowledge for pervasive computing to be discovered in practice. The development of a Coco AI-enabled wearable can provide nurses with the cognitive support they need in current practice through easy bedside access to data management, interpersonal communication, and cognitive task assistance.

Finally, this project also studied and tackled the transdisciplinary challenges inherent in technological development in healthcare. Healthcare practices are challenging design contexts, involving a knowledge gap in medical expertise and clinical practice, high stakes concerning human health protected by well-established policies and protocols, and complex practice dynamics specific to each healthcare department. Consequently, it is crucial for disciplines outside the medical field to interact with the practice and the people within them to gain a deeper understanding for proper design alignment. Gaining access to medical practice might seem challenging, but it is fundamental in order to sufficiently design interventions to improve healthcare practice. This project exemplifies these principles and shows that medical experts, such as pediatric nurses, are passionate and enthusiastic about collaboration to achieve the best care possible. Therefore, the conclusive advice of this project for transdisciplinary collaboration is to start by gaining a deeper understanding of the specific healthcare practice by experiencing it together, reflecting on it, and generating new insights for improvements iteratively discovered through applying Research through Design.

Figure 67: Coco pretotype

Personal Reflections

Engaging in healthcare practice

This design project has been an eye-opening experience for me, as it is my first time working on a design project for a specific profession within the healthcare sector. Designing for healthcare practices can be intimidating and challenging due to their complexity, well-established practices, high stakes regarding human well-being, and a clear knowledge gap in medical expertise. I feel fortunate to have met the right people who were enthusiastic and passionate about this project. Their support was crucial in helping me gain access to key contacts in healthcare and enabling me to visit actual medical practices as an intern. This experience has shown me that collaborative projects in technology research and design for healthcare require the commitment of transdisciplinary teams. Without such collaboration, one can only make theoretical and hypothetical assumptions about the practice, limited to their own expertise perspective.

Even with the support, access, and cooperation of people in the medical field, I must emphasize that medical design projects are inherently challenging to understand as an outsider. Gaining a deep understanding of specific medical practices requires significant reflection and analysis, as well as the ability to zoom in and out of details to process information effectively. Throughout this project, I experienced moments where I felt lost, unable to see a clear solution that could improve an already optimized and well-established professional practice like bedside nursing. However, the Research through Design methodology has been instrumental in helping me navigate these periods of uncertainty.

Complex problems cannot be solved solely through thought and analysis, they require active engagement with the practice itself. Interactions such as conversing with nurses, shadowing them during their work, or having them use a simple model in a real-world setting are crucial for surfacing information and gaining insights necessary for further development.

My experiences with the bedside nursing practice throughout this project have deepened my respect for nurses, who face immense pressure in their roles. Pediatric nurses are tasked with the critical responsibility of caring for seriously ill and vulnerable children while simultaneously managing complex multitasking demands. These include planning, patient care, medical assessment and documentation, and maintaining a compassionate demeanor as the primary point of contact for patients and their families. The daily challenges they face in balancing these duties are truly remarkable. However, I want to emphasize that projects in the healthcare sector, such as this one, also require a significant degree of mental and emotional resilience from outsiders who observe or engage with the medical field. Interactions with vulnerable patients and the gravity of medical practices may not be suitable for everyone and should therefore be clearly communicated.

Double Degree Graduation

This project was part of my Double Degree graduation in MSc Design for Interaction (DfI) and MSc Integrated Product Design (IPD). Throughout the project, I was continuously challenged to apply the skills and knowledge I gained from both Master's programs. I extensively used Interaction Design methods to analyze bedside nursing practices. Methodologies such as context mapping, user-centered design, and participatory design were integral to my interaction-based approach. These methodologies provided invaluable insights into user experience, human-product interaction relationships, and the identification of user needs.

The integrated perspective on design helped me connect everything from practice and technology to research and design. In past projects within the IPD Master's program, the multi-faceted nature of properly incorporating different design techniques and methods was invaluable for project synthesis and the eventual proposal. Visualization techniques used during ideation and conceptualization were instrumental in creatively exploring and defining design concepts. The development of the concept pretotype and proposal model utilized my skills in 3D modeling, 3D printing, and Arduino electronic prototyping to achieve validation through practical testing.

Although the project did not reach a high Technology Readiness Level or produce an optimized concept with defined material properties and cost assessments, this outcome was anticipated. Such results are nearly impossible for a graduation project that starts at the fuzzy front end of design, particularly in a challenging context like healthcare. This field demands extensive research to build a thorough understanding necessary for effective design. Despite these challenges, my training as an IPD student was crucial in integrating the convergence of design, technology, and research.

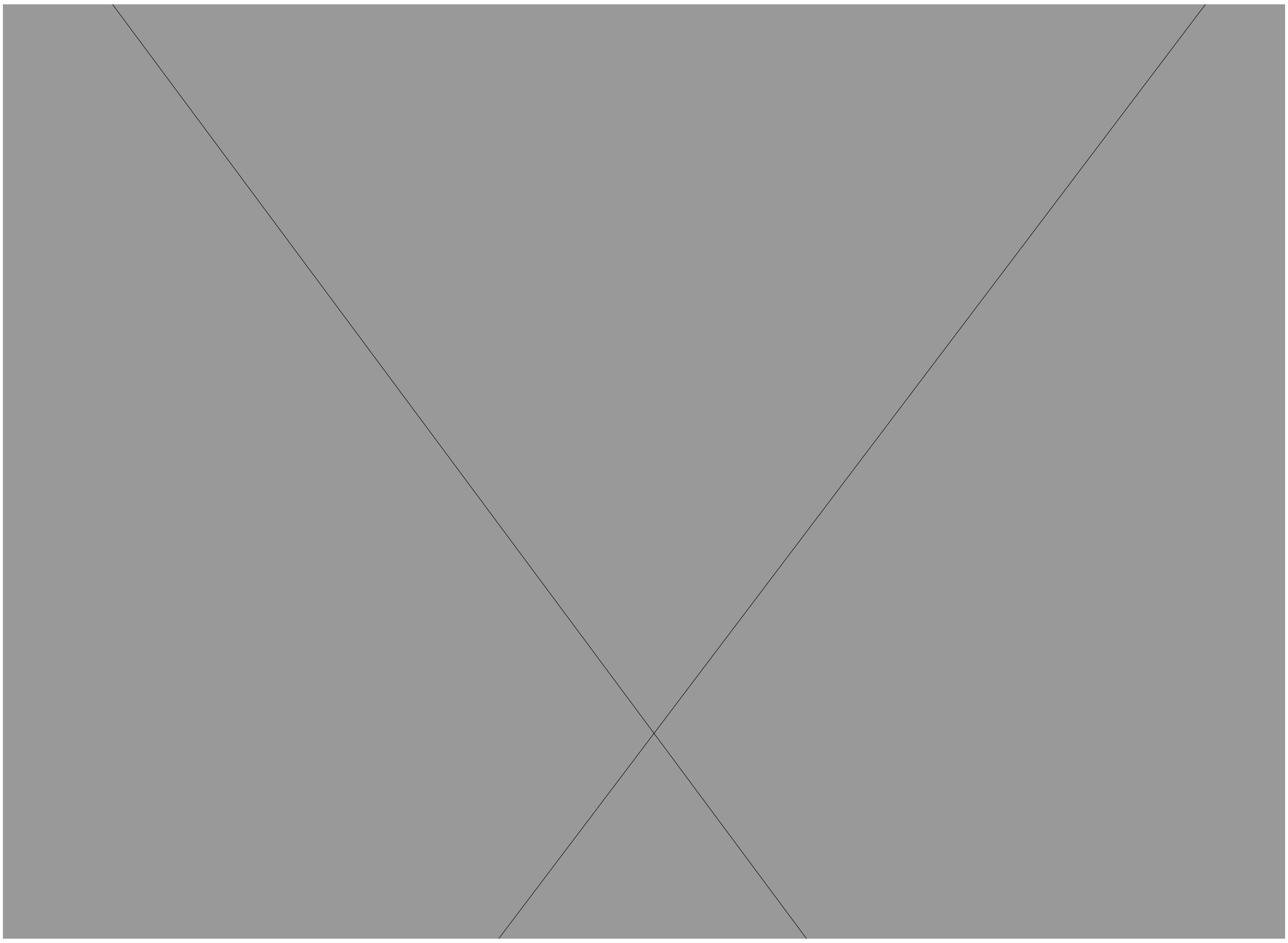


Figure 68: The visits to the Children's Thorax Center at Erasmus MC Sophia have truly been eye opening.

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Appendix

Personal Project Brief – IDE Master Graduation Project

Name student Victor Verboom **Student number** 4,559,908

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT

Complete all fields, keep information clear, specific and concise

Project title Designing robotic agents as objects with intent for nursing at hospitals.

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

Robot technology provides new perspectives for designing interventions in healthcare. This is especially true for the nursing practice, which is struggling with staff shortages and increasing workloads (Adams et al., 2021; CBR, 2022). An increasing number of healthcare initiatives apply robotic technology to assist disabled people in need; relieve workload for caretakers; and transform patient experiences at hospitals, see the examples at figure 1. With this in mind, this project will focus on designing robotic agents for nursing in collaboration with the Erasmus Medical Center in Rotterdam, to continuously collect, reflect, and apply insights for Human-Robot Interaction (HRI) research.

However, challenges arise with this new dimension in product intelligence and interactivity. Designing robotic agents involve expressing, realizing, and embedding robotic interventions in dynamically complex practices. Earlier research by Rozendaal (2016) on this subject proposes the certain notion of `Objects with Intent' (OwI's). In short, OwI's focuses on agents that embody the meaning of everyday things as essence for their robotic agency. A framework builds upon this notion by approaching OwI's through three key concepts shown in figure 2 (Rozendaal et al., 2019). So far, research on OwI's has been mostly analytical and requires further exploration of setting this knowledge into practice.

Ultimately, the goal of this project is to bridge the gap between user-centered design and robot engineering as part of a double degree in Msc Design for Interaction (DfI) and Msc Integrated Product Design (IPD). Setting OwI's theory into practice, through designing everyday objects as collaborative robotic agents for nursing to accommodate explorative and applied research in the field of HRI.

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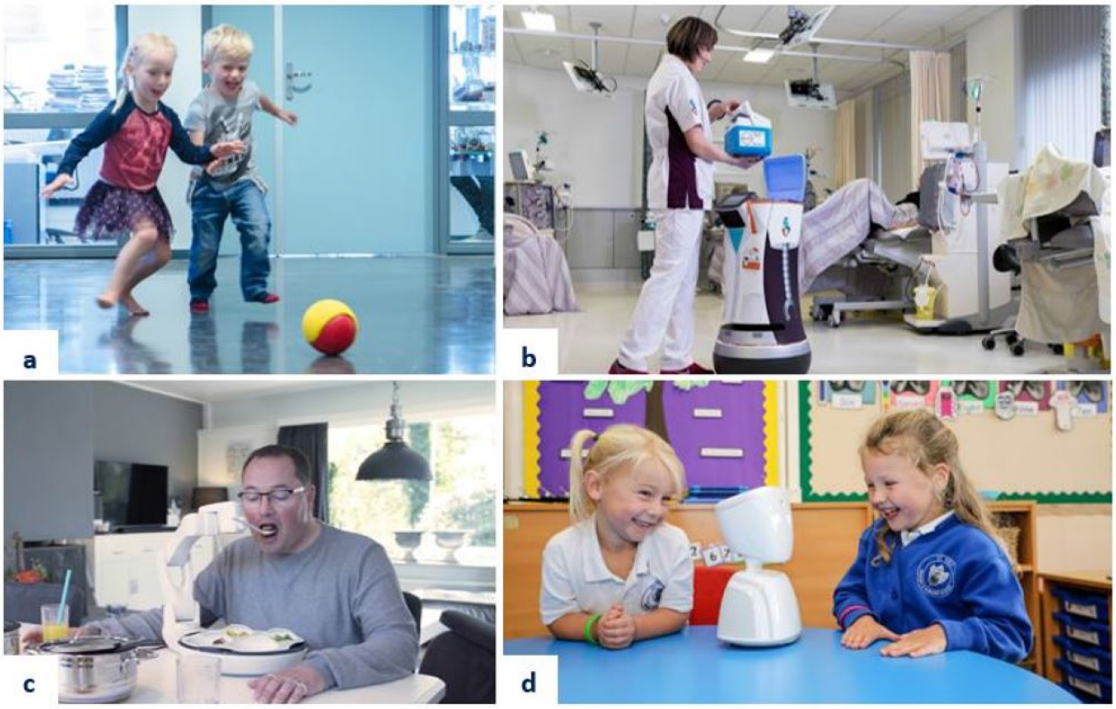
introduction (continued): space for images



a) *Fizzy ball: play for hospitalized children (Boudewijn, 2020);* **b)** *Hospital Delivery Robot (Relay Robotics);*
c) *Feeding Robot (Obi);* **d)** *AV1 telepresence robot (No Isolation)*

image / figure 1 Examples of healthcare initiatives using robot interventions.

Analytical Framework of Objects with Intent (Rozendaal et al., 2019)

Concept and Explanation	Informing concepts and theories	Questions
Framing How people *frame*, or interpret, OwI's when interacting with them.	Different types and levels of agency (AT), and different stances (Dennett).	Can the object be framed as a *designed artifact* that can have *intentions of its own*?
		How is this framing *established*?
		Can the object be successfully employed as a *collaborative partner*?
Embedding How the use of OwI's is *embedded* in a particular context.	"Object" orientedness, inseparability of subjects and objects in contexts (AT).	In which ways is the interaction with the object *enmeshed* and *coordinated* with the environment?
		Is there a *two-way interaction* between the object and the context?
		How can the object be successfully embedded *in the environment?*
Transformation How the collaborative partnership *transforms* over time.	Development, internalization/ externalization (AT).	How does the object promote *change* on an *individual* and *collective* level?
		Can *different phases* be identified through which these changes occur?
		How can the object be successfully employed for making an intended *long-term impact*?

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image / figure 2 [left] The analytical framework of Objects with intent (Rozendaal et. al., 2019); [right] References

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

The nursing practice at hospitals is a complex context, with many challenges involving feasibility, viability, and desirability. Designs have to abide to the high workload practice of nurses, while also follow strict hospital regulations and feasibility hurdles in robot-tech development. Then there is also the multitude of multidisciplinary experts that are involved in such development: designers, roboticists, psychologists, organizational scholars, nurses and patients. Creating a complex design context with overarching transdisciplinary needs. Overcoming collaborative barriers and creating transdisciplinary platforms is a necessary step that current transdisciplinary initiatives are focusing on (Arzberger et al., 2023). However, the underlying reason for transdisciplinary collaboration in the first place is the development of technical innovations that truly support the nursing practice. For example, past innovation projects in this context are often delayed in development or end up being abandoned, such as the *Incubator Stop Light* and the *Baby Length Meter* from the Create4Care initiative (Erasmus MC, 2023). Resulting from tunnel visioning on intervention development, rather than focusing on the essence of desired change in practice it needs to achieve. This is where HRI design can have a pivotal role in providing a structural approach and emphasizing the importance of certain design actions for transdisciplinary endeavors.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence) As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Develop a design approach to apply the objects with intent framework in practice through a case study involving a design proposal of a robotic agent for nursing at the Erasmus Medical Center.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

Why? To generate insight and awareness. It is crucial for transdisciplinary teams to have the right approach for future robot-assisted innovation projects. Therefore insight based on past project experiences and awareness of consequential effects in design approach need to be generated.

What? Developing a design approach. The deliverable of this project will mainly revolve around a formulated design approach. A design approach can provide transdisciplinary experts not only with valuable insights, but also guidance in how to approach designing for this context.

How? Reflection through iteration. The design approach will be formulated based on the insights gathered from a design case study at the Erasmus MC. The case study will use participatory and user-centered design techniques to analyze the nursing practice. Followed by design exploration through iterative prototyping, resulting into a design proposal for further development. The project will apply an iterative design process inspired by Agile Design methodology, and emphasize reflective to maintain aim for the desired effect in practice.

Project planning and key moments

To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a ***kick-off meeting****,* ***mid-term evaluation meeting****,* ***green light meeting*** *and* ***graduation ceremony****. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting 17 Nov 2023

Mid-term evaluation 30 Jan 2024

Green light meeting 11 Jun 2024

Graduation ceremony 9 Jul 2024

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

The project is grounded in my fascination for robotics innovation and specifically chosen to fit the double degree graduation in Msc Design for Interaction (DfI) and Msc Integrated Product Design (IPD). Having experienced both master programs differentiating themselves as a certain design expertise in development, I pursue to bridge the gap between interaction design research and integrated realization of design engineering. This could serve especially valuable for in the innovative field of Human-Robot Interaction, due to the dual complexity in engineering and interaction design that is involved. This will also mean that competencies and knowledge from both master programs will be used interchangeably throughout the project. For example, research techniques (e.g. interviews, observations, flow charts, and ecosystem analyses) from both master programs will be used to understand and develop with involved users accordingly. The same will apply for the design process which will alternate between visualization activities (e.g. idea sketching, concept drawing, 3D Modelling) and prototyping techniques (MVPs, embodied prototyping, and prototype testing) learned from both masters programs.

Pursuing a future as an UX designer, I set my personal learning ambitions in deepening my knowledge of interaction design and develop robotics related prototyping skills, such as 3D printing, sensory electronics and coding in Python.

Project planning

Gantt chart

Student name: Victor Verboom

Student number: 4559908

Starting date: November 17, 2023

Graduation Project title:

Designing robotic agents as objects with intent for nursing at hospitals.

Months	November			December				January					February				March				April				May					June				July	
Dates	13-17	20-24	27-01	04-08	11-15	18-22	25-29	01-05	08-12	15-19	22-26	29-02	05-09	12-16	19-23	26-01	04-08	11-15	18-22	25-29	01-05	08-12	15-19	22-26	29-03	06-10	13-17	20-24	27-31	03-07	10-14	17-21	24-28	01-05	08-12
Calender week	46	47	48	49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Academic week	2.1	2.2	2.3	2.4	2.5	2.6	Christmas holidays		2.7	2.8	2.9	2.10	Spring break	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	3.10	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	4.10	5.1	5.2
TASK ↓ / PROJECT WEEK →	0	1	2	3	4	5			6	7	8	9		10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Milestones																																			
Kick-off meeting	nov-17																																		
Midterm evaluation											jan-30																								
Green light meeting																															jun-11				
Graduation ceremony																																			jul-09
Cycle 1: Explore & Define																																			
Lit. research: Multidisciplinary HRI view																																			
Context analysis																																			
Transformation evaluation																																			
Design intervention																																			
MVP building																																			
MVP testing																																			
Reflecting period																																			
Cycle 2: Integrate & Specify																																			
Lit. research: Embedding in context																																			
Context analysis																																			
Transformation reevaluation																																			
Design intervention																																			
Low-fidelity prototype building																																			
Low-fidelity prototype testing																																			
Reflecting period																																			
Cycle 3: Optimize & Finalize																																			
Lit. research: Expressive potential																																			
Context analysis																																			
Optimizing design intervention																																			
High-fidelity prototype building																																			
Iterative usability testing																																			
High-fidelity prototype testing																																			
Reflecting period																																			
Run-out period (buffer zone)																																			
Documentation & Presentation																																			
Reporting for thesis																																			
Video																																			
Presentation																																			

Design process - case study Erasmus MC