FireFly Forest

Designing an Augmented Reality Experience for Children to distract during Venipuncture Procedures

Master thesis by Sophie Thomassen

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Glossary

Augmented Reality (AR): A technology that overlays digital content on the real world, enabling interaction with both virtual and physical environments.

AR Pass-through View: The feature in the AR headset that allows users to see both the real world and digital content simultaneously.

Pass-through AR: A form of AR where the user sees the physical world through a headset or device's camera, with digital overlays added on top.

Virtual Reality (VR): An immersive digital environment that blocks out the real world, creating a fully virtual experience.

Venipuncture: The medical procedure of puncturing a vein with a needle to draw blood or administer medication.

Sense of Control: A psychological state in which individuals feel they can influence or manage their environment or situation, helping reduce anxiety.

Comfort Care: A care approach used in pediatric healthcare that focuses on making medical procedures as comfortable as possible through positive experiences and distraction techniques.

Design Elements: The specific elements of the AR experience such as visual, auditory, and interactive features.

Design Goal: The overarching objective that the final design aims to achieve, ensuring alignment with both user and stakeholder needs.

Key Features: Design elements derived from research insights that contribute directly to achieving the design goal by addressing specific challenges or requirements.

Medical Pedagogical Caregiver (MPC) / Child life specialist:

Minimum Viable Product (MVP): A simplified version of a product created to test core concepts and gather feedback with minimal development.

Interactive Elements: Components of the AR experience that allow users to actively engage, such as making a fist or interacting with fireflies.

Prototype: A preliminary version of the final product developed to test design elements and gather feedback before final implementation.

Stakeholder: Any individual or group with an interest or concern in the project's development and outcomes, including children, nurses, and medical staff.

Nocebo Effect: The phenomenon where negative expectations about a procedure or situation can increase perceived pain or anxiety.

Preface

Hello there,

My name is Sophie and I am the writer of this report.

The underlying purpose of this report is to help children cope with pain and anxiety during medical procedures. As a source of inspiration, I introduce this project with a reflection on my own childhood, followed by my values as a designer.

As a child, my mind was filled with endless fantasies. Every night before bed, I would imagine entire worlds and stories, hoping they would become real in my dreams. I was a huge fan of *Avatar: The Legend of Aang,* being completely mesmerized by the waterbenders. I would copy their movements, convinced that if I would just try hard enough, I too could control water one day. In my mind, it wasn't a fantasy—it was a goal, something that could be achieved if I just tried hard enough.

But as we grow up, we start to feel the weight of reality. You learn about gravity, about physics, about the constraints of the real world. You start hearing what is and isn't possible. Bit by bit, that childlike certainty fades, and the once-unshakable belief that you could fly or move water with your mind starts feeling naïve.

It's a shame that we let go of our imagination like that. Because the charm of fantasy is that it is not limited by its feasibility. A dream does not have to be practical to be meaningful. To dream is to explore possibilities before questioning them. Just like you do in a brainstorming session. After all: nothing is wrong in a brainstorming session, right?

This imaginative, boundless thinking is one of my favourite things about design. The early concept phase, where there is no right or wrong, where ideas from completely different disciplines intersect and merge—that is creativity at its finest. And beyond creativity, I believe that good design is about more than that. It should evoke something. It should make you feel.

Now how can we translate that imaginative thinking into design?

We live in an evermore digitalising era: The Digital Revolution (Is that how they will call it in history books in 100 years?). New technologies emerge endlessly and I am especially drawn to technologies like Artificial Intelligence and Augmented Reality. They bring us closer to turning the impossible into reality. They offer us new tools to shape experiences, to push past the boundaries we once accepted as fixed. They are, quite literally, tools to bring our fantasies to life, to translate imaginative thinking into design.

For this project, I dove into the world of Augmented Reality, exploring how it can transform a medical procedure into a soothing fantasy experience. Because if there is one thing I believe, it is that we should never stop dreaming of better experiences. Not just for ourselves, but for those who need it most.

I hope you enjoy reading it!

Best regards,

SOPHIE THOMASSEN

Abstract

Introduction
Venipuncture is often a stressful and painful experience for children. Virtual Reality (VR) has been researched by Erasmus MC Sophia Children's Hospital as a distraction method to reduce anxiety during medical procedures. While effective, VR can cause a loss of control, as children are fully immersed and disconnected from their surroundings. To address this issue, this project explores Augmented Reality (AR) as an alternative that allows children to stay aware of their environment while still providing an engaging distraction. The research was guided by a research question.

Research Question
How can an AR experience be designed for venipuncture procedures to effectively distract children aged 6–12, reducing their perception of pain and anxiety* while maintaining their sense of control?

*Measuring pain and anxiety is not included in this project, the main focus is on effective distraction measured outside of medical context.

Research
A combination of theoretical and practical research provided key insights into designing an effective distraction tool. From theory it was proven how focus shifting can influence pain and anxiety. Mapping the patient journey revealed that pre- and post-procedure experiences play a crucial role in ensuring AR distraction is effective, as children's anxiety builds before the procedure and their perception afterward can influence future experiences. A key challenge was balancing the needs of the nurse and the child. While nurses require efficiency and minimal disruption to their workflow, children need positive reinforcement and a sense of control. Ensuring that AR could be seamlessly integrated into clinical practice while still offering children agency over their focus became a fundamental part of the design goal. Research also showed that maintaining a sense of control during the procedure depended on where the child directed their attention, with some preferring to watch the needle while others sought full distraction. This is mapped in the Define chapter.

Define
To accommodate different coping strategies, three child archetypes were identified:

The Monitor – Prefers to watch every step to feel in control.
The Curious – Seeks distraction but wants to remain somewhat aware.
The Blunter – Actively avoids looking at the procedure and seeks full distraction.

The design had to allow all three viewing direction, ensuring flexibility. To guide the design process, a design goal was stated.

Design Goal
"To create a distracting and calming (AR) experience for children during venipuncture, guiding their attention to an engaging digital world, without hiding the physical procedure, in a way that improves the procedure experience for both the child and the nurse, while being easy to implement in a clinical workflow."

Develop
From the design goal, four key themes emerged: distraction and calmness, sense of control, procedural experience, and clinical implementation. These themes guided the co-creation process with children and other design methods, leading to the identification of key features that formed the building blocks for ideation.

Through this process, the FireFly theme was developed. To evaluate the design goal, an AR prototype was built in Unreal Engine. Pre- and post-procedure experiences were also explored to improve the effectiveness of the AR interaction. These were discussed with the client and turned into concept directions.

Deliver
The final design FireFly Forest is presented. It includes interactive fireflies, a breathing exercise and positive reinforcement elements that align with the venipuncture steps. Testing the AR prototype with children aged 9–11 in a simulated, non-medical venipuncture setting showed that the experience was intuitive, engaging, and effective in shifting focus away from the procedure. Children were not able to recall the majority of the performed ‘medical’ actions and described the experience as appealing, calming and fun.

To address the pre- and post-procedure experience, two additional concepts were developed:

Lumi’s Portal – A waiting room interaction that introduces children to the FireFly world before the procedure, making the AR experience feel more familiar.
Lumi’s Adventure Booklet – A post-procedure reward system where children collect stickers, reinforcing positive associations with medical visits.

These concepts are not tested with the target group but serve as idea directions and conversation starters for further design.

Conclusion
While the prototype showed promising results, testing in a medical context is needed to assess its real-world impact during actual venipuncture procedures. The design successfully demonstrated that AR can allow for different viewing directions, but further research should focus on adapting the experience to a sense of control. Moreover, it is necessary to evaluate implementation in clinical workflows, and refine interactions based on real hospital settings.

Ultimately, FireFly Forest shows how mandatory procedure steps can be translated into rewarding challenges through effective distraction. By integrating pre- and post-procedure support, accommodating different coping styles, and aligning with clinical constraints, this project presents a structured and engaging solution to make venipuncture less distressing for children.

Contents

AI-generated image depicting "Child with VR headset". Created with DeepAI, 2024.

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Project Brief

Origination of the project

Medical procedures, especially for children, can provoke intense anxiety and pain, turning routine treatments into highly stressful experiences. One such procedure is **venipuncture**, where blood is drawn from a vein (Figure 1). For children, particularly those with chronic conditions requiring frequent blood tests, venipuncture is often reported as one of the most distressing aspects of treatment. High levels of anxiety can worsen the perception of pain, leading to long-term fears such as **needle phobia**, which may result in children avoiding necessary medical procedures (Kennedy et al., 2008).

To address this challenge, TU Delft and Erasmus MC Sophia Children's Hospital are collaborating to develop an **Augmented Reality (AR) experience** designed to take their attention away from the venipuncture procedure and thereby reducing pain and anxiety. This project builds on the success of previous research conducted at Erasmus MC Sophia, where Virtual Reality (VR) applications were used to prepare children for surgical and MRI procedures, significantly **reducing their anxiety levels** and, in turn, their reliance on **pain medication** (Van Spaendonck et al., 2023). The full preparatory project brief can be found in Appendix A.

Despite the successes of VR in medical settings, it also introduces new complications. To address these challenges, this project will explore the potential of AR as a new medium. Before discussing the limitations of VR and the possibilities of AR, it is important to first understand their distinct definitions and differences.

Figure 1. A venipuncture procedure in the Sophia Children's Hospital (VriendenvanSophia, 2024).

Technology

Used hardware and technology

Figure 2 shows the 'Reality-Virtuality Continuum' with a practical example, illustrating the spectrum of technological possibilities between the entirely physical world and the fully digital world. The continuum is divided in four categories: (Arena et al., 2022).

1 **Reality (Real Environment, RE)**
The fully physical world with no digital elements added. In the example, this is represented by a hand in front of the IDE faculty building.

2 **Augmented Reality (AR)**
Digital elements are overlaid onto the physical world. In the example, a small dinosaur with a speech bubble appears within the real environment. (This can be achieved using, for example, AR glasses or smartphone cameras).

3 **Augmented Virtuality (AV)**
Physical elements are added into a predominantly digital world.

4 **Virtual Reality (VR)**
The fully digital world, with 100% virtual objects and no real-world elements, creating complete immersion for the user.

Anything that is not RE nor VR and fits in between the two, falls under the umbrella term Mixed Reality (MR).

Reality-Virtuality Continuum

A spectrum of technological possibilities

Figure 2. "Simplified representation of a Reality-Virtuality Continuum" from "Augmented Reality: A class of displays on the reality-virtuality continuum" by Milgram et al. (1994), used under CC BY.

Thus, an essential distinction between VR and AR is the user's **level of immersion**. VR completely immerses the user in a digital environment, while AR keeps the real world visible. According to prior VR research from the Erasmus MC Sophia, children experience **a loss of control** when they are wearing the VR headset. They do not have a grip on reality, since all they see is a digital world and that completely hides the venipuncture procedure. Some children even look underneath the VR headset to maintain awareness of their surroundings, indicating a need to stay connected to reality during the procedure (B. Dierckx, personal communication, 2024). Recognizing this limitation, the focus of this project is about AR and how to maintain a sense of control for the patient by seeing their real-world environment and staying grounded in their surroundings.

To develop the AR experience for this project, the Meta Quest 3 MR Head Mounted Display (HMD, hereafter referred to as 'headset') is used, since it is readily available at the TU Delft. It has a pass-through feature, which means the user can see the real world as through their own eyes, but with an added layer of digital elements (AR). Figure 3 showcases what it looks like to see through this headset, seeing a real, physical living room with digital webbrowser tabs projected on top of it. However, the headset is not transparent; the user sees through two external cameras as shown in Figure 4. This is called 'Video See-Through Augmented Reality', which is the specific type of AR that is focused on in this project, and will be referred to when talking about 'AR'.
The prototype is developed in Unreal Engine using software compatible with the Meta Quest 3, but the concept of the designed outcome is intended to be adaptable for implementation on other AR headsets as well.

Figure 3. Pass-trough feature of the Meta Quest 3, recognizing a hand and projecting a digital layer of web browser tabs onto the 'real' physical world: a living room in this case (Zeng, 2024).

Figure 4. The Meta Quest 3 Mixed Reality Head Mounted Display with two cameras, featuring Video See-Through Augmented Reality (Meta, 2024).

Context

The domain of the project

The development of children is fundamentally shaped by the environments they interact with, from their immediate family to the broader societal structures around them (Nederlands Jeugdinstituut, 2022). According to Bronfenbrenner's ecological systems theory, the experiences of a child are influenced by multiple interconnected layers, and the closer the layer, the more impact it has. In the closest layer, called the microsystem, we find healthcare (Figure 5). Bronfenbrenner's theory suggests that the healthcare system plays a crucial role in a child's growth, development and well-being. Therefore, it is crucial to create the most positive hospital experience possible, especially during medical procedures, all within the constraints of the hospital setting. This project takes place in the Sophia Children's Hospital (Figure 6). The figure shows the hospital main entrance, service desk and venipuncture room. The character is retrieved from an online tour called Joep's adventure.

The Sophia Children's Hospital (hereafter referred to as 'the Sophia' or 'the hospital') is part of the Erasmus Medical Center in Rotterdam. Founded in 1863, it is the oldest children's hospital in the Netherlands, providing highly specialized care to children from birth to 18 years and treating thousands of patients annually (Erasmus MC, n.d.). Rather than following standard Care As Usual (CAU), the Sophia strives to establish Comfort Care as its new benchmark. Unlike CAU, which typically offers a flyer or video for procedural guidance without specific focus on comfort, Comfort Care prioritizes the patient's comfort, considering it as important as the medical treatment itself (Procedurele Comfortzorg - PROSA Kenniscentrum, 2023). For instance, the distraction tools at the venipuncture department, child-friendly language guidelines and pain reducing tools are all part of Comfort Care. This project's outcome, which focuses on reducing procedural distress, aligns closely with the principles of Comfort Care.

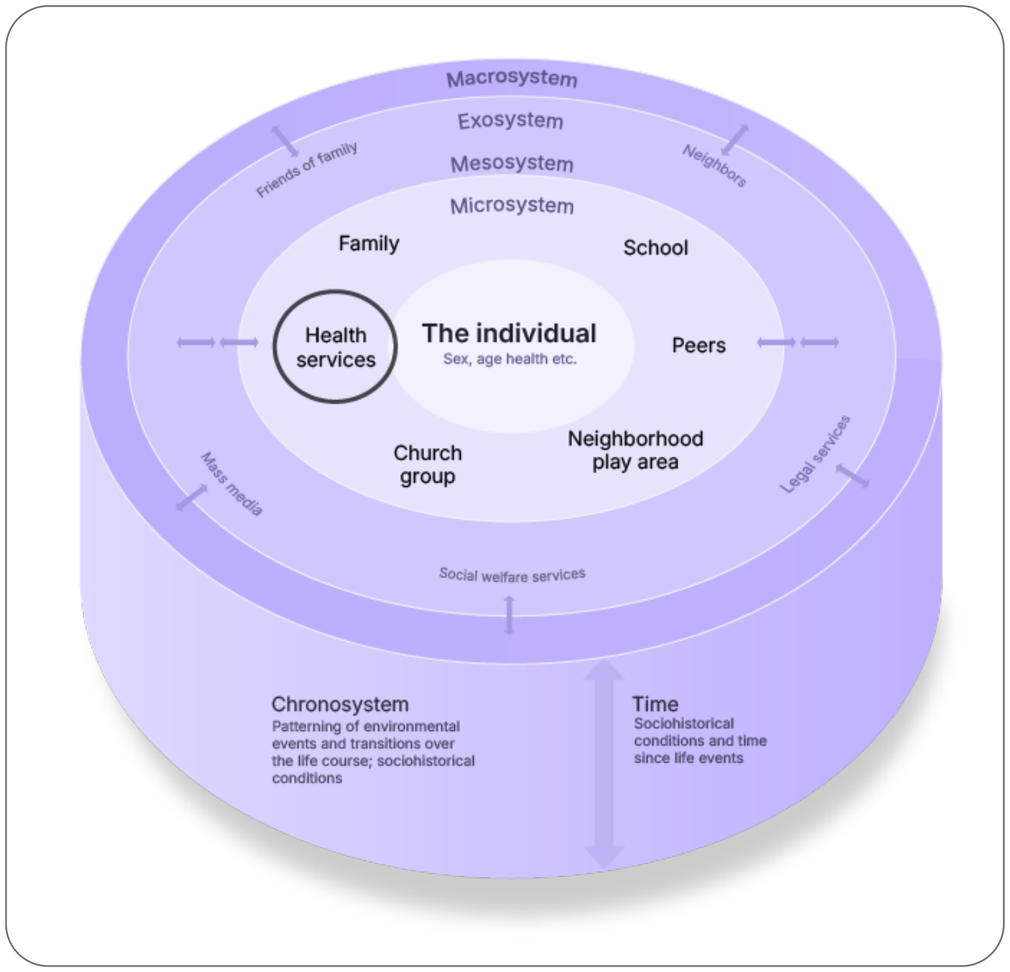


Figure 5. "Ecological Theory of Development" by Bronfenbrenner (1977), used under CC BY.

Existing different (distraction) methods to reduce pain and anxiety during venipuncture will be covered further in the report. AR, being one of those tools, is a new method at the Sophia and offers new opportunities for a particular age group. In fact, mixed reality applications are very suitable for an age of children from 6-12 years old (B. Dierckx, personal communication, 2024). This is because the mixed reality headset fits and is effective from the age of 6. In addition, cognitive calming methods, such as using reasoning to control emotion, only work for ages 12 and older. It is therefore, that this research specifically targets the age group of 6-12 years.

Figure 6. Venipuncture room, main hall and entrance hall of the Erasmus MC Sophia Children's Hospital through "Joep's Adventure" (Sophia, n.d.).

Approach

The general approach of the project

To navigate through the project and design process, the **Double Diamond method** is used as shown in Figure 7 (Design Council, 2023). The model consists of two diamonds that represent the two phases of design: exploring the problem and finding the solution. The shape of the diamonds is metaphorical, representing the thought process that varies between diverging and converging. Figure 7 provides an overview of the Double Diamond, but in short the four phases are:

1 Discover

Fully immerse in the context, understand the problem, and gather insights.

2 Define

Refine and articulate the problem and design goal, identifying opportunities and challenges.

3 Develop

Develop the solution using iterative design approaches and methodologies.

4 Deliver

Present the final design, evaluate, refine, and propose implementation strategies for clinical integration.

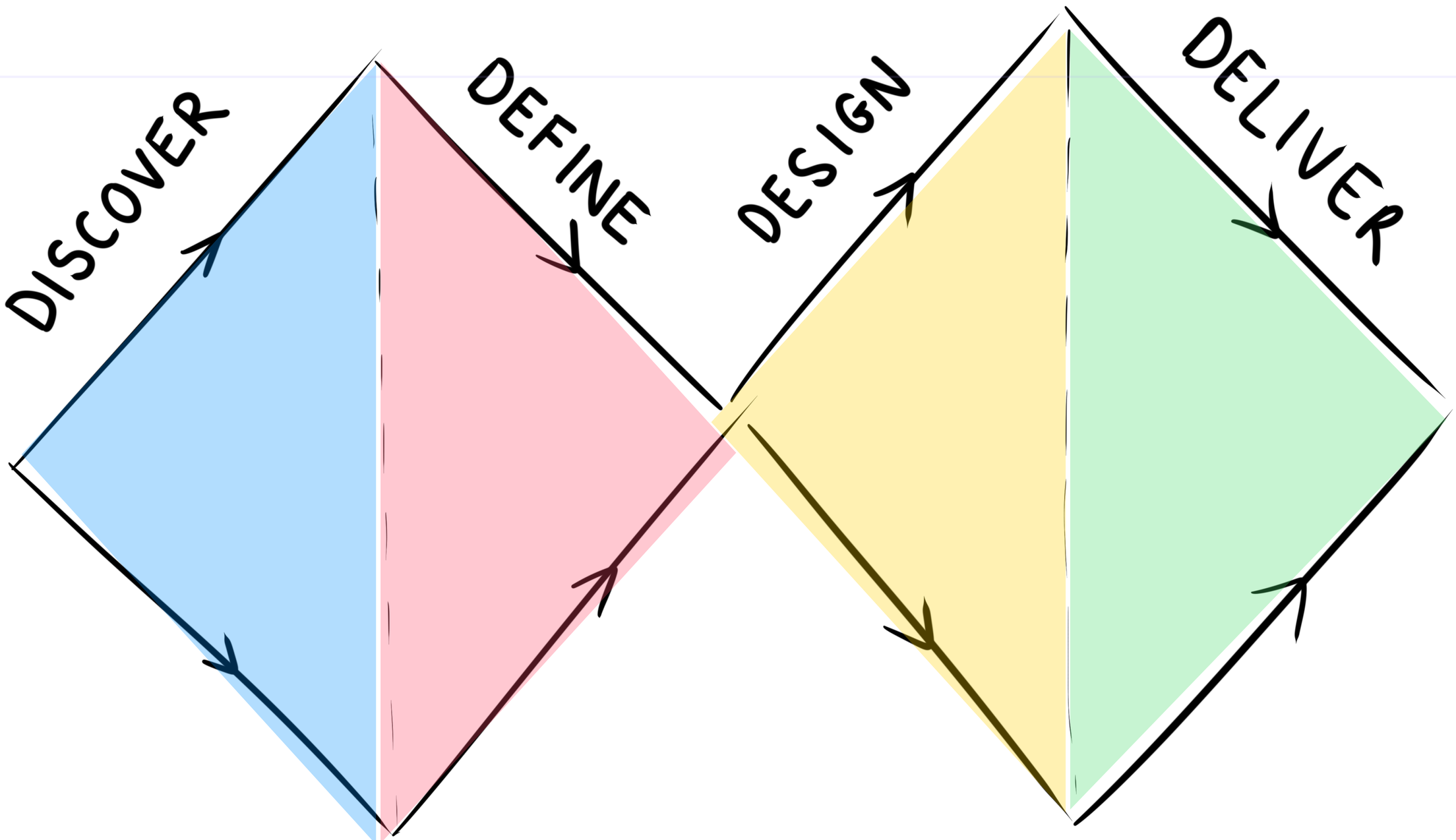
Main Research Question

The project revolves around a **main research question**:

> How can an **AR experience** be designed for **venipuncture procedures** to effectively **distract** children aged 6–12, **reducing** their perception of **pain and anxiety*** while maintaining their **sense of control**?

Sub-questions (Figure 7) have been developed to support a comprehensive answer to the main question. If relevant, their relation to the main question will be illustrated at the beginning of a chapter.

*Measuring pain and anxiety can disrupt medical procedures and typically requires quantitative research, which is not feasible within this project timeframe. Consequently, this project will focus on testing AR as a distraction tool outside of medical contexts, whilst ensuring that the final product can be easily integrated into clinical settings.



1	2	3	4
CH1.1: An overview of research methods and questions	Q2.1: What challenges and opportunities for the design can be identified?	Q3.1: What steps were taken to reach the final design?	CH4.1: Presenting the final AR design and concept directions for the pre- and post-procedure experience
Q1.2: How does distraction influence pain and anxiety in theory?	Q2.2: What does a sense of control mean per patient?	Q3.2: How can the design goal serve as guidance for the design process?	Q4.2: How does the target group experience the AR interaction?
Q1.3: What do venipuncture procedures look like in the Sophia?	Q2.3: What is the design scope for the AR experience within the venipuncture process timeline?	Q3.3 What types of visual, auditory, and interactive components are most effective in calming children and distracting them during venipuncture?	Q4.3: How do healthcare professionals estimate the design's feasibility for implementation?
Q1.4: What are current effective (distraction) tools and why?	Q2.4: How is a direction for the design process realised?	Q3.4: What key features can be identified for the four different themes?	Q4.4: Does the concept meet the design goal?
Q1.5: Who is involved and what are people's needs?	Q2.5: What should the desired interaction feel like?	Q3.5: What concept themes are explored that lead to the final concept?	Q4.5: How feasible, desirable, and viable for real-world adoption is the AR solution?
Q1.6: How is a sense of being in control realised at the Sophia?	Q2.6: What must the design accomplish?	Q3.6: How was the AR experience developed in Unreal?	Q4.6: How scalable is the final design, and what are its long-term application prospects?
Q1.7: What are the possibilities and limitations for AR in this context?		Q3.7: How can the pre- and post-procedure experience enhance the AR interaction?	Q4.7: What are the key steps and considerations for implementing the AR distraction tool in a clinical setting?
Q1.8: What captures attention for the target group?			
Q1.9: What conclusions can be drawn through answering the research questions?			

Figure 7. Design process overview using the Double Diamond design approach, accompanied by sub research questions (Q1.1) or subtitles per chapter (CH1.1).

Scope and limitations

Boundaries of the project

This project explores the potential of Augmented Reality (AR) as a tool to enhance the venipuncture experience for children, reducing their negative experiences and potentially contributing to preventing needle phobia. By using AR's ability to overlay calming digital elements onto the real world, the design aims to provide distraction while preserving the child's sense of control. The collaboration between TU Delft and Erasmus MC Sophia offers access to valuable expertise in design and pediatric care, ensuring the solution is informed by real-world needs and medical insights.

AR Development
However, the project also comes with certain limitations. As a designer rather than a specialized AR developer, the AR prototype developed for this study has (technical) limitations and does not represent the full potential of what could be implemented in a clinical setting. While the prototype captures the core elements to test the research question with, it may not reach its full potential when it comes to appearance, technical aspects and integration expected in a final product.

Short and long-term scope
The aim of the Sophia is to design a prototype that could be implemented by tomorrow, meaning that it should be feasible with current technologies and capabilities. Therefore, existing software Unreal Engine 5.3 is used to develop the prototype, in combination with hardware from the Meta Quest 3. The project focuses mainly on the near future with current technologies and thus a short-term scope. The possibilities of the far future (long-term scope) are considered later in the report, as there are interesting opportunities regarding e.g. scalability, but will not be an emphasis in the report.

Testing in medical context
Additionally, due to the timeframe of the project, a request and approval from the Medical Ethics Committee (METC) was not feasible. Thus, direct testing in medical contexts, where children undergo venipuncture procedures, is outside the project scope. As a result, user testing will focus on simulating the procedure in non-clinical settings, using analogous objects and scenarios to evaluate the design's effectiveness. Despite these constraints, the insights gained from this project will provide a solid foundation for further development and refinement in future iterations.

1

Discover

The Discover chapter focuses on understanding the problem context, target group, and design opportunities. By combining theoretical insights, stakeholder input, and practical observations, this chapter unpacks the challenges of venipuncture procedures for children. Each chapter revolves around a sub research question, which will be concisely answered in the final conclusions chapter. The insights gained in this chapter lay the foundation for defining the design direction.

1.1 Research approach

An overview of research methods and questions

Main research question

How can an **AR experience** (Q1.7) be designed for **venipuncture procedures** (Q1.3, Q1.4 & Q1.5) to effectively distract **children aged 6–12** (Q1.8), reducing their perception of **pain and anxiety** (Q1.2) while maintaining their sense of control (Q1.6)?

Research questions

This section outlines the sub-research questions derived from the main research question, noting that their numbering corresponds to the chapter numbers. To address these sub-research questions, a range of research activities were conducted. Figure 8 provides a summary of these activities, detailing each one and illustrating how they correspond to the associated research questions

Q1.2: How does distraction influence pain and anxiety in theory?

Q1.3: What do venipuncture procedures look like in the Sophia?

Q1.4: What are current effective (distraction) tools and why?

Q1.5: Who is involved, and what are their concerns?

Q1.6: How is a sense of being in control realised at the Sophia?

Q1.7: What are the opportunities and limitations for AR in this context?

Q1.8: What captures attention for the target group?

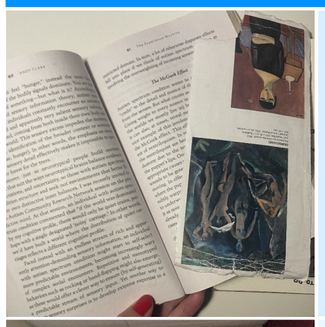
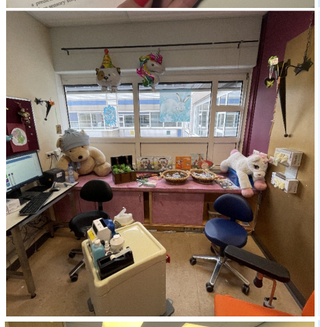
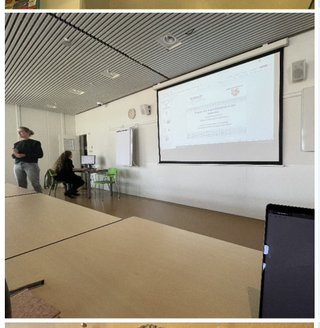
Image	Research activity	Explanation and motivation	Question
	**Literature study**	Reviewed existing research and theories on pediatric pain, anxiety management, and the impact of immersive technologies like AR/VR in healthcare. This study helped contextualize the project within broader research, supporting decisions around using AR for anxiety reduction and shaping the theoretical framework for the design. Also valuable insights were gained on the target group.	Q1.2 Q1.5 Q.1.6 Q1.7 Q1.8
	**Observations**	Observed venipuncture procedures in a clinical setting, focusing on the behaviors, interactions, and responses of children, caregivers, and healthcare providers. This direct observation provided valuable insight into how theoretical concepts apply in a real-world context, helping to bridge the gap between literature and practice and compare the two.	Q1.2 Q.1.3 Q1.8
	**Interviews**	Conducted structured and semi-structured interviews with healthcare professionals, parents, and (former) patients to gather insights on their experiences, needs, and perspectives. Interviewing allowed for in-depth exploration of personal experiences, helping uncover emotional and practical insights that might not be visible through observation only. Chapter 1.5 provides an overview of the interviewees, full interviews can be found in Appendix C.	Q1.2 Q1.5 Q.1.6
	**Attending lecture**	Attended a lecture on Comfort Care for pediatric healthcare professionals to understand the approaches and methods that are taught in their education. Provided insights into their ways of working, personal experiences and opinions.	Q1.2 Q1.4 Q1.6
	**First-hand experience**	First-handedly underwent the venipuncture procedure to empathize with children's physical and psychological challenges. This activity helped to directly experience the sensations and anxiety children might feel, providing a personal perspective that aims for understanding beyond theoretical knowledge.	Q1.2 Q1.3 Q1.6

Figure 8. Research activities that were done in the research phase with an explanation and motivation, and relation to the research question.

1.2 Influence of distraction

How does distraction influence pain and anxiety in theory?

For many children, a hospital visit is perceived as frightening or even a source of deep anxiety. Among all medical procedures, venipuncture—also known as a blood draw—is described by children as one of the most painful and distressing experiences (Ryu et al., 2022). **Approximately three out of four of children under 12 years old report high levels of pain and distress** during venipuncture (Atzori et al., 2018; Bölenius et al., 2014; Humphrey et al., 1992).

Untreated pain during these procedures can have long-term consequences, such as distorted pain perception and the development of negative psychological effects (Weisman et al., 1998). These effects include procedural distress ("procedureel leed" in Dutch), a phenomenon that greatly impacts the child's care experience. **Procedural distress** can result in failure and avoidance of necessary medical procedures, the use of coercion, the emergence of anticipatory anxiety, distrust in healthcare providers, and even post-traumatic stress and **needle phobia** (Leroy, 2021).

To understand how these factors interact, it is important to examine the model of procedural distress (Figure 9). This model highlights three key factors: the child's experience of pain, their anxiety levels, and their focus of attention on the procedure versus comforting or neutral (Baxter, 2013). The following sections dive deeper into each of these aspects.

1. Pain (sensation/experience)

Pain refers to the physical sensation experienced during the procedure. The intensity of pain is highly variable and differs from child to child. Research suggests that effective pre-procedural pain relief, such as analgesics, can enhance the effectiveness of other comfort-enhancing techniques (Leroy, 2021).
Implication for AR Design: For an AR experience to function effectively as a distraction tool, physical pain should be minimized beforehand through medical interventions like analgesia.

2. Anxiety (emotion)

Anxiety occurs when the child perceives the procedure as threatening, triggering a fight, flight, or freeze response. This emotional reaction often leads to resistance, which can result in the use of coercion. When (physical) coercion is used, adults firmly grasp the child or even tie the child down until the procedure is completed. This practice only worsens anxiety and creates anticipatory fear for future procedures (Leroy, 2021). Procedural anxiety is closely tied to the child's ability to predict events. Providing children with a sense of control through expectation management—e.g., explaining the steps and avoiding surprises—can significantly reduce anxiety (Leroy, 2021). However, parental distress remains a critical, unpredictable factor, as it is contagious and strongly influences the child's emotional state (Brown et al., 2018).

3. Focus of attention (psychological-cognitive activity)

The level of procedural distress is heavily influenced by where the child's attention is focused. When attention is directed toward fear and pain, these sensations intensify. Conversely, shifting the child's focus to comforting or engaging stimuli reduces distress. There are two types of distraction (Baxter, 2013):

Passive Distraction
Activities such as watching TV or looking at a book.

Active Distraction
Interactive activities, such as playing a game or solving a cognitive task. These tasks should be tailored to the child's developmental age, as cognitive ability can vary from chronological age.

Research suggests that active distraction is more effective than passive distraction for procedural distress. Effective distraction strategies use elements like: arousing curiosity, desensitizing fears, capturing attention, interactive learning and relational engagement.

An example of this is a study where children, immersed in a virtual reality experience, were so distracted that they did not even notice they were undergoing a puncture procedure (Lichaam van Coppens, 2018).

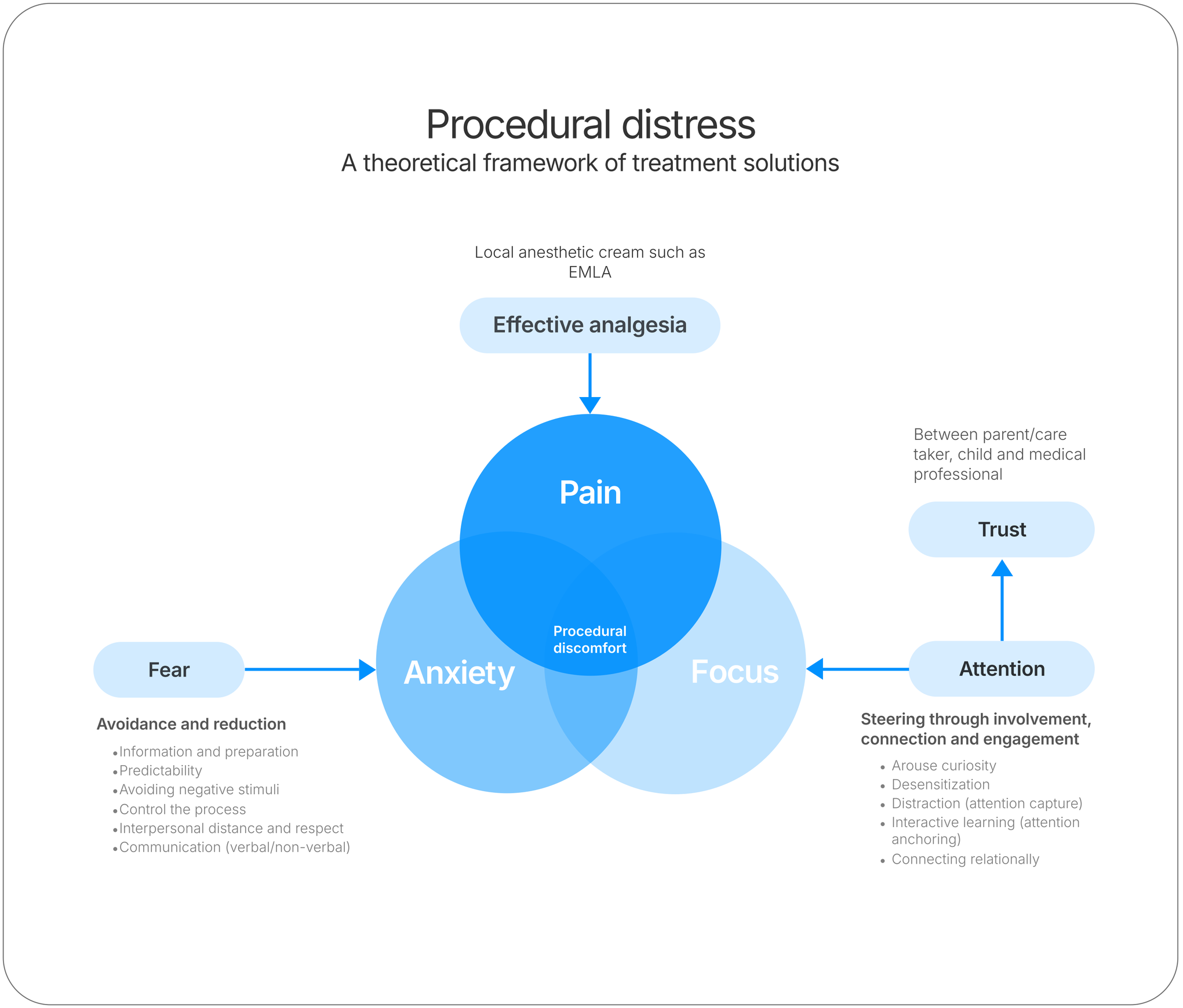


Figure 9. "Procedural distress and its multimodal treatment" from "Van trauma naar vertrouwen" by (Leroy, 2019), used under CC BY.

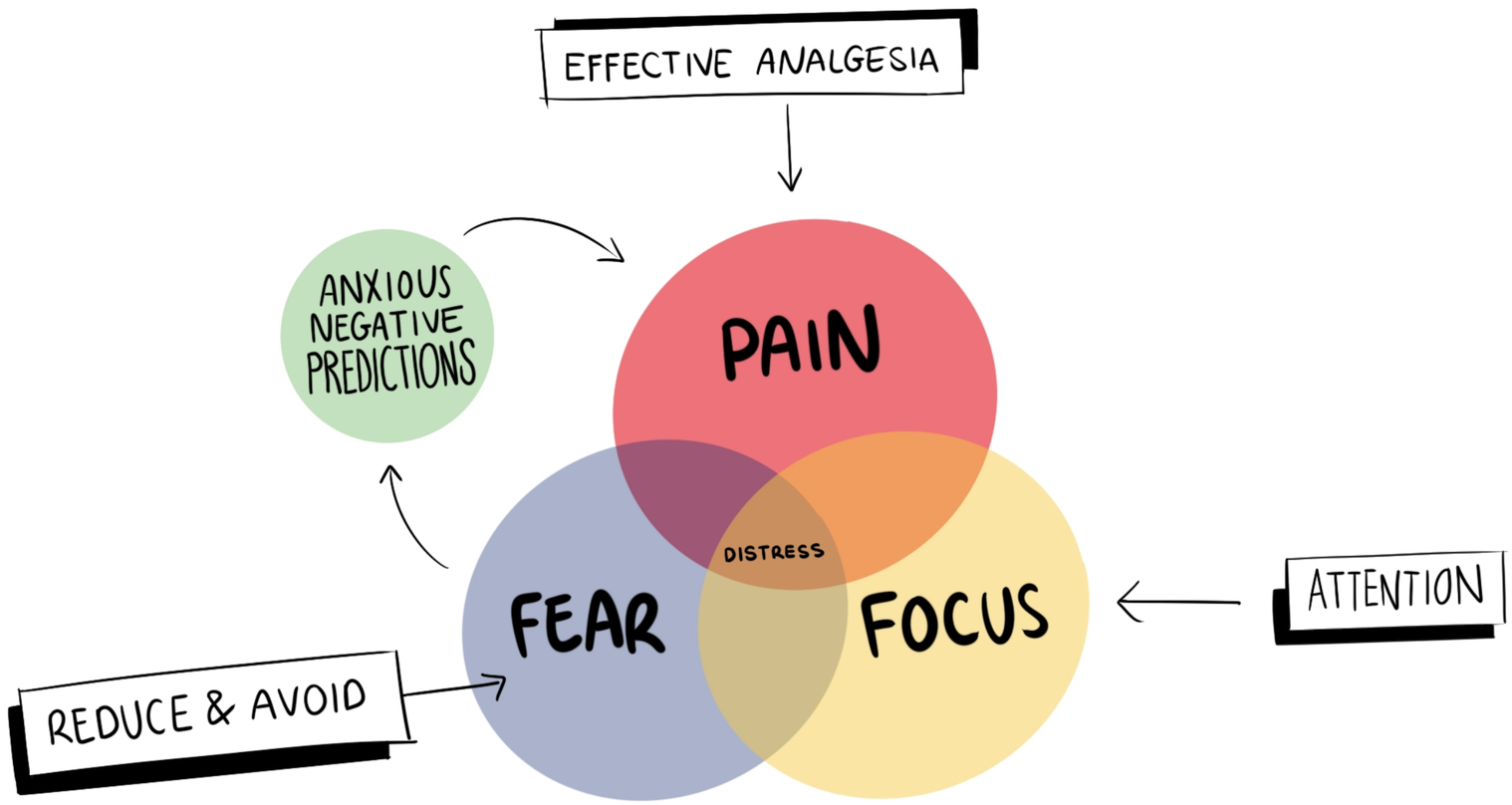


Figure 10. " "Procedural distress and its multimodal treatment" from "Van trauma naar vertrouwen" by (Leroy, 2019), with addition of theory by Clark (2023), used under CC BY.

Another theory by cognitive philosopher Andy Clark describes how pain is highly influenced by prediction, rather than perception. In his book 'The Experience Machine' he states that if there is an expectation of pain, pain will occur. Likewise, the opposite is true, if we think about a placebo effect. We predict relief, and it occurs. The antonym of a placebo is a nocebo, which means that negative expectations or fears lead to a worsening perception of pain, even when there is no pain in reality. In Clark's book he describes how a construction worker has an accident in which his foot gets stuck in a nail. The man suffers in pain, but in the end it turns out that his foot and the nail had never touched. However, the perception of pain did take place and thus there is actual suffering. This is the reason that a needle injection hurts so much for children when they are focused on the pain. We should be aware of the occurring nocebo effect venipuncture triggers.

So if a scared child expects a needle puncture to hurt a lot, then, regardless of the measures taken, the procedure will hurt a lot. This direct influence of fear on pain is added to the standard model of procedural discomfort, see Figure 10.

1.3 Venipuncture procedures

What do venipuncture procedures look like in the Sophia?

Observations

To understand venipuncture procedures in Sophia Children's Hospital, twelve procedures were observed over two days. Attention was given to the patient, their caregivers, and the nurse. Data was collected in a detailed table (Figure 11), and an inductive thematic analysis was performed (Figure 12). The raw data table is included in Appendix B.

Observations revealed that coping strategies vary greatly from child to child. Discomfort is often rooted in fear, especially in children who have had negative prior experiences, though some children face procedures with no prior exposure. Each child requires a personalized approach that meets their specific needs, yet in all cases, it is critical to ensure the child maintains a sense of control.

Additional influences come from nurses, parents or caretakers, and the hospital environment itself. Observations showed that systemic issues within the hospital can increase stress for nurses and parents, which, in turn, affects the child's experience. Parents said "Quick, we are in a hurry for our next appointment". Conversely, positive support from caretakers has a calming effect and enhances the child's overall comfort, with phrases as "You did so well!".

The room's environment also plays a significant role. While there was little observed benefit from the standard room setup, children's stress levels noticeably rose when they were not in familiar or child-friendly surroundings. Comments like, "But why am I not in the nicer room?" made them feel upset. So, in rooms lacking child-appropriate decorations or comforting elements, children's stress levels were visibly higher.

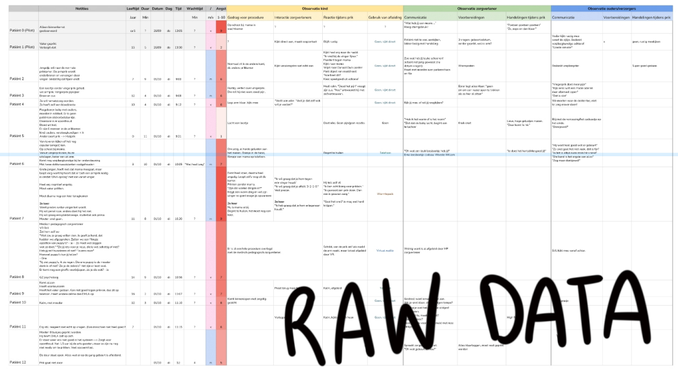


Figure 11. Process overview from raw data table analysis of twelve procedures with annotations to thematical clusters. A bigger view of the data table can be found in the Appendix.

Distraction tools box

Visual negative emotions

Fear caused by prior negative experience

“That thing always hurts so much” (Patient)

Discomfort for the child was very noticeable, as there was a lot of crying and fear involved. Children knew what they did not like, as they were talking about prior negative experiences.

Type of approach

Specific needs and preferences of a child

Following protocol

“Do you want it fast, or at your own tempo?” (Nurse)

According to this quote, the tempo of the procedure is different from the child’s tempo. This is an interesting discrepancy, could it not be the same?

Systemical errors

Mistake in the system

Type of puncture

“What is this? Why is it not working?” (Nurse)

There were several procedures in which the digital system was not functioning. This caused uncertainty about the type of puncture, leading to extra stress.

Room ambience

Calmness, quietness

Crowded room

“Why am I not in the nicer room?” (Patient)

The room ambience also has a strong influence on the experience for the patient. There are multiple rooms, ranging from a lot of distractions for children to no distractions at all.

Coping strategies

Distraction tool

Distraction by recognizing a heroe

Direct watching, direct influence

∗Points at Donald Duck poster∗
(Patient)

The room ambience also has a strong influence on the experience for the patient. There are multiple rooms, ranging from a lot of distractions for children to no distractions at all. From the twelve observations, two patients actively noticed a Donald Duck poster.

Positive interaction towards child (by nurse)

Complimenting child on personal topic

Complimenting child on actions

Using high-tone voice

“You’re doing great! High five!”
(Nurse)

Nurses vary a lot in their interaction and empathy with the patient. However in general, there was a very positive attitude from the nurses. They were very supportive and complimenting children a lot.

Parental involvement

Parents not using positive language

Parents on the background

Thanking the nurse

“We have to go to the doctor, don’t take too long!” (Parent)

The majority of the parents during the procedures remained on the background, but some sentences that indicate a hurry can cause stress for nurses. Their language can really set positive or negative tone for the procedure.

Figure 12. Formed clusters from themes with further elaboration and quotes.

Patient scenario

What does the hospital visit look like from a child's perspective? What would be their initial thoughts and perceptions? To empathize and immerse with the user group, a venipuncture procedure was undergone, allowing for first-handedly feeling the procedure as a child would. Starting from the moment of arrival outside of the hospital, initial thoughts were written down.

Figure 13 shows the patient scenario. Within the hospital, long and unpredictable waiting times are a significant source of stress. Background noise, including the sounds of crying or distressed children, evoke feelings of fear. The uncertainty about when the procedure will start further triggers restlessness and anxiety, making the waiting experience quite unpleasant.

Arrival at the hospital, a very big and intimidating building.

Waiting until 'my parents' have received their ticket..

On my way to the blood withdrawal department.

Finally I can go inside, the nurse welcomes me and I am intrigued by the room.

I am sitting down in the chair and choosing my preferred arm.

There she goes.. it hurts a bit more than expected.

HOW DOES IT FEEL THROUGH THE EYES OF A PATIENT?

Arrived, it looks so much like a hospital; everything is so pale and serious.

The noise here is horrible, children are crying and screaming! Will that happen to me?

This is where the crying comes from.. and I have to get in there as well... scary!

You can really see the blood flowing through the tubes.

She cleans the wound again, and gives me a bandage. It is much more than just puncture.

I get to choose something I like: nice!

Figure 13. Patient scenario, a day in the life of a child at the venipuncture.

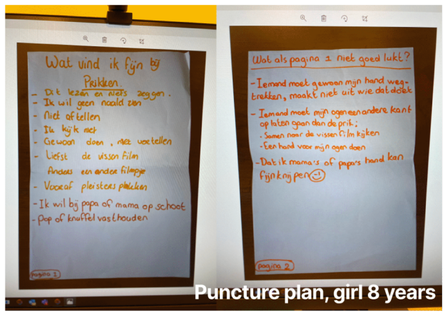
Patient Journey Map

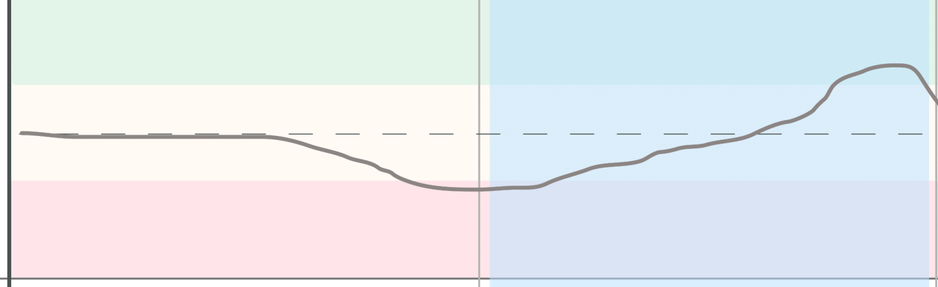
To better understand the venipuncture process and identify areas for improvement, a patient journey map was developed in collaboration with a Medical Pedagogical Caretaker (MPC) / Child Life Specialist. This professional specializes in guiding children through medical procedures, offering emotional and practical support for managing pain and anxiety. The patient journey map illustrates key moments of heightened fear and anxiety, as well as opportunities for intervention. The following findings were identified:

The waiting room
Anxiety levels are at their peak while children wait for their turn. The unpredictability of waiting times, coupled with the distressing sounds of other children undergoing procedures, significantly increases fear. Opportunity: Intervening at this stage can help reduce pre-procedure anxiety and improve the overall experience, as confirmed by the MPC.

Empathy form nurses
Variability in how medical assistants address children's fear and anxiety was noted. The skill of detecting fear and providing reassurance, differs strongly per individual.

Round off (Post-procedure experience)
The final interaction after the procedure has a lasting impact on the child's overall perception. A positive closing experience, such as offering a compliment or small reward, can significantly improve their mood and confidence. Conversely, a lack of positive reinforcement may result in the child associating the visit with negative emotions.



Phases	1 Appointment with the attending physician at the outpatient clinic	2 Appointment (on demand) with childlife specialist
Steps	• Consultation • Measuring, weighing • Doctor decides whether or not to take blood samples • Schedule blood collection	• MPC researches what is the child's experience? • Parents are called with questions about the child • Diversion options are offered • Lancing plan is made (together with child) • Additional visit to hospital and puncture room
Environments	Outpatient corridors Sophia hospital	Home → Hospital
Touchpoints	GP referral, Treating physician, HiX file	Phone call, hospital website
Mood		
Pain points	Child often asks, "is it going to hurt?" → is already developing anxiety. Choice between capular (finger) or venous (arm) is established here, can differ from practice	
Gains and opportunity areas	Physician could already identify anxiety here → E.G.: Ask parent&child how child it reacted at earlier vaccinations?	Child feels involved.
Questions	How can you identify anxiety earlier to help the whole process?	How can you make the child feel involved and taken seriously?
Conclusions and ideas	If children already indicate anxiety: already offer an option here with AR and make a note in HIX.	This step occurs only on demand. Without reaching out to the MPC, nothing happens at home → Idea: already start the AR experience or something related to it at home

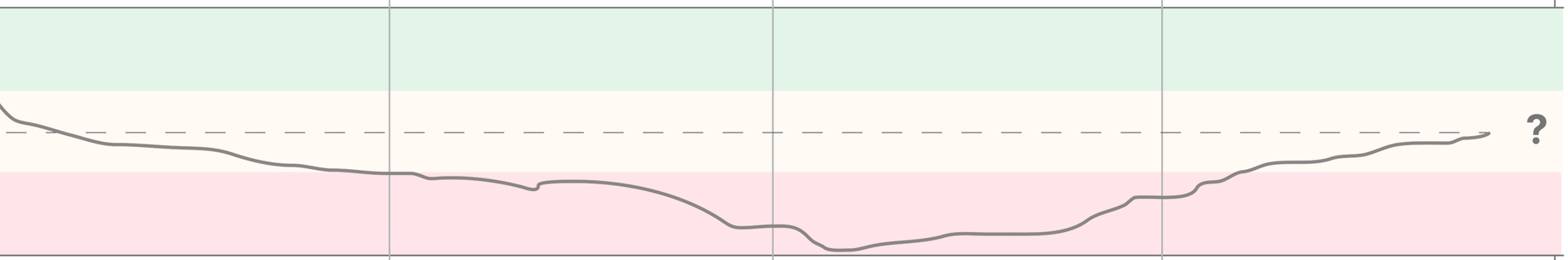
			
3 Arrival at hospital	**4 Waiting room**	**5 Puncture room**	**6 Round off**
• Getting there, traffic jam/ov/bike • Search for a parking space • Sign in at column for day ticket • To the blood collection department	• Signing in at the front desk • Waiting for the chairs • Waiting at play area • Waiting time can range from 5 minutes to 30 minutes	• Greetings nurse • Sit in puncture chair • Tell date of birth • Clean arm • Puncture	• Plaster • Picking a gift • Departure • Eating ice cream/chocolate milk?
Outside → Main entrance	Blood withdrawal department	Puncture room	Puncture room → Outside
Traffic-signs, Public transportation systems, ticketing kiosk, Day ticket, Signs/Receptionist directions	Doctor's assistant, Submit ticket, Posters, flyers Toys, coloring pages	Physician assistant/nurse practitioner	
			
With problems on the way there, this already provides stress, especially for parents	Nurses are not always present at the front desk. Chairs not very comfortable, not always space. Can be very crowded (>10 people). Few parents go to the play area and you hear a lot of crying.	Nurses too busy to help → do not properly assess anxiety. With multiple punctures, tension remains high for a long time. If the puncture fails (because of anxiety) this level remains high for a long time.	Sometimes little attention is paid to closure → Ends with a bad memory
Have a cute mascot (elephant) here.	Children take what is there to do: coloring sheets, lego, etc. and go do something with it	Often the child is given a compliment/ something nice to say. Nurses prepare the needles in advance (do not open needle in front of the child).	Child gets to hear what went right → Explicitly.
How to make the journey there as stress-free as possible?	How can a waiting room act as positive preparation for lancing?	How can you create an intervention that supports and distracts the child but does not interfere with the nurse's clinical workflow?	How can you end the child's experience as positively as possible and give good courage for a possible next visit?
Perhaps start doing something fun already here? Decrease stress for child?	Long indeterminate time, tension is mounting. Good idea to start the AR experience or something related here already!	Nurses vary greatly in their empathy and way of dealing with anxiety. They also do not have a lot of time. Take this disparity + lack of time as a starting point, and design around this.	What happens here is important: you take home the last memory. Make sure the experience ends with a focused compliment + something nice → Gift, chocolate/ice cream.

Figure 14. Patient Journey Map filled in together with a Medical Pedagogical Caretaker/Childlife specialist. The blue highlighted step only occurs when the need for an MPC is required.

1.4 Current interventions

What are current effective (distraction) methods and why?

This chapter maps out current methods to mitigate pain and anxiety, divided in three categories. Each category is explained in Figure 16, showcasing their intended use and effectiveness. Highly effective tools tend to be very popular.

1. Distraction box tools
At the venipuncture department of the Sophia Children's Hospital, a box containing various distraction tools is available for use during procedures (see Figures 15 and 16). The department comprises approximately eight nurses who are responsible for performing the procedures. However, interviews and observations (see Appendix C.4, C.5, and C.6) indicate that these tools are rarely used by them. The nurses and nurse managers reported that the tools are not part of their routine practice.
The primary reasons for this include time constraints and the perceived pressure from parents or caregivers, who often express urgency due to tight schedules for hospital visits. As a result, nurses feel compelled to speed up the procedure, which discourages them from incorporating distraction techniques. But even if they would have the time, some nurses could not really argue why they were not using it, other than "I do not know, it is just not in my system." This raises the question whether a distraction tool can be designed in a way that aligns with the nurses' workflow, potentially improving efficiency while reducing stress for both patients and caregivers.

2. Pharmacological & physiological tools
The most common intervention for venipuncture procedures is a pharmacological solution: EMLA cream, which is a topical anesthetic that numbs the skin to reduce pain from the needle.

As stated by the Medical Pedagogical Caretaker (MPC) and other healthcare professionals, this intervention is essential if the child is scared and perceives pain.

3. Digital tools
During a pediatric lecture, a group of approximately twenty students was asked whether they had ever used a VR headset during a medical procedure. None of them had experienced this, as such tools are typically reserved for special cases where an MPC is present. This leads to an important question: Could an AR headset be developed and implemented without requiring the intervention of an MPC?

Takeaways

Effective elements for distraction tools are:

- Breathing exercises: Effective for calming children and adds a natural response of muscle relaxation.
- Engaging tasks: Providing a task is a highly efficient way to distract and engage children.
- Bright, vibrant colors: These effectively capture and hold a child's attention.
- Multisensory experiences: Tools that engage additional senses, such as vibrations (e.g., Buzzy) or temperature variations (e.g., heat/cold packs), enhance the distraction effect.

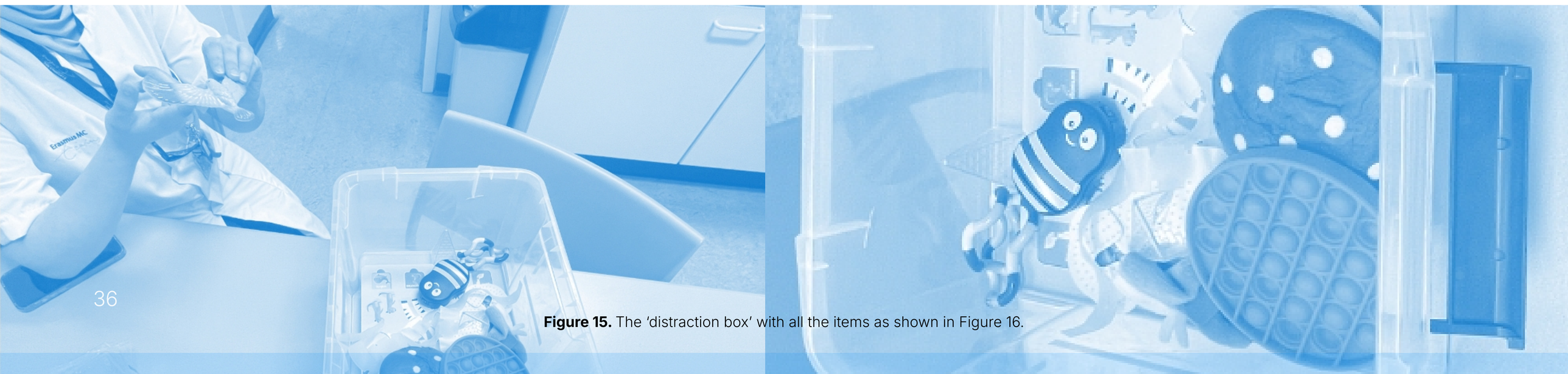


Figure 15. The 'distraction box' with all the items as shown in Figure 16.

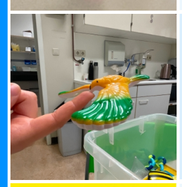
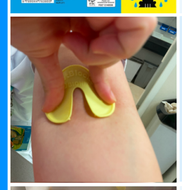
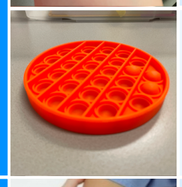
		Name	Explanation	Effectiveness	Takeaway
Distraction box tools		**Buzzy**	The bee vibrates and therefore provides an extra incentive/distraction. The bee can already be spotted on stickers in the hallways.	✅ Very popular	Additional sense for distraction → Stimulus vibration. Use bee in combination with VR glasses?
		**Bubble blow**	The child is asked to blow and then to count or prick bubbles.	✅ Very popular	Breathing exercise is effective as that calms down, task of counting/ pricking is good addition.
		**Balance bird**	The child has to balance the bird on his finger. Then the is question is asked: “Where does the bird fly to?”	Popular	Bright colours work effectively together with a physical and a cognitive task.
		**Lookbook**	A booklet containing expressive, attention-grabbing drawings.	Popular	Additional sense for distraction → Stimulus vibration. Use bee in combination with VR glasses?
		**Mat with studs**	Kind of an extremely mild version of acupuncture (distraction around the prick), also leaves an imprint and is therefore not being used.	Never being used	Distracting pain with other stimulus.
		**Mat with bubbles**	A rubber mat in which bubbles can be pushed out and function as a counting exercise.	Never being used	Cognitive task exercise.
Pharmacological & physiological tools		**EMLA cream**	EMLA cream is a topical anesthetic that numbs the skin to reduce pain from the needle. It needs to be applied about an hour before the procedure to be fully effective.	✅ Very popular	With high fear and pain levels, this measurement should be taken at all times, as recommended by MPC.
		**Heat/cold packs**	Warm and cool packs shift focus to the sensation of temperature change, creating a contrasting sensory experience that diverts attention from pain.	Popular	Additional sense for distraction → Warmth or cold. Also a ‘medical placebo’ for some children.
Digital tools		**VR Headset**	The child is taken away from reality and does not see the procedure. An MPC attends the procedure and asks about the things the child sees during the VR experience.	Used on demand only for scared children	The child is completely being distracted, but also does not see anything what is really happening.
		**Projections**	Projections on the ceiling or wall to distract.	Popular	The looking direction is far from the procedure.
		**Video on phone/tablet**	The bee vibrates and therefore provides an extra incentive/distraction. The bee can already be spotted on stickers in the hallways.	✅ Very popular	A video is easy to use and organize, and very efffective.

Figure 16. A table of current interventions in the Erasmus MC Sophia Hospital at the blood draw department, the majority of them is part of ‘distraction box’ which is a box that stores the different tools.

1.5 Stakeholders and concerns

Who is involved and what are people's needs?

Stakeholder interviews

To establish a better understanding of needs and wishes of all the stakeholders, various interviews were conducted. These varied from structured interviews with a duration of an hour, to semi-structured interviews in ten minutes, to short conversations of a couple sentences.

Figure 17 shows all the interviewees, an explanation about the interview and the responsibility of the interviewee for a venipuncture procedure.

Appendix C contains the full interview overview with questions. The order and number ranking of the interviewees corresponds with Figure 17. Figure 19, 20 and 21 show a summary of interviews with three key stakeholders: the patient, the nurse and the MPC.

Stakeholder mapping

From the patient journey map and interviews, a stakeholder map that showcases underlying relations and specific concerns was created, see Figure 18. It shows four different relevant stakeholder groups that are involved in a venipuncture procedure.

1. The child and its family
2. The Erasmus MC Sophia
3. The venipuncture department (of the Sophia)
4. The AR developer

All groups have influence on how the experience feels for the patient and the most influential stakeholders are closest to the center of the figure.

	Interviewee	Explanation	Procedure relevance
1	**Ex-patient**	An extensive interview with an ex-patient that has needle phobia due to prior negative puncture experience. This interviewee was able to express the needs for the target group in a verbal manner.	(Ex) Target group
2	**Medical Pedagogical Caretaker (MPC) / Childlife specialist**	An extensive interview with an MPC to understand the protocol that is followed when a child fears venipuncture. Information was also very useful to understand the patient journey and the target group better.	Personal guidance for the child in case of fear and anxiety
3	**Healthcare psychologist**	When an MPC is not sufficient for the child and fear and anxiety are deeply rooted, a healthcare psychologist steps in to find and treat the underlying cause.	Psychological treatment of deeper rooted problems for venipuncture
4	**Manager venipuncture department**	An extensive interview with the manager of the venipuncture department to gain valuable insights about the organisational background of the procedure.	Logistics and organisation behind the procedure
5	**Nurse (3x)**	Short, semi-structured conversations to gain first hand insights and opinions of the performers of venipuncture procedures.	Executing the venipuncture procedure
6	**Coordinator blood withdrawal department**	Short conversation on why distraction methods are not being used and what the difficulties thereby are.	Directing nurses who are responsible for blood withdrawal
7	**Parent**	Short conversation on experience at the venipuncture department.	Guiding their child (patient)
8	**Child/patient**	Short conversation on experience at the venipuncture department.	Target group

Figure 17. A schematic overview of interviewees during the research phase. Data from the interviews is used throughout the entire project, and full interviews can be found in Appendix C.

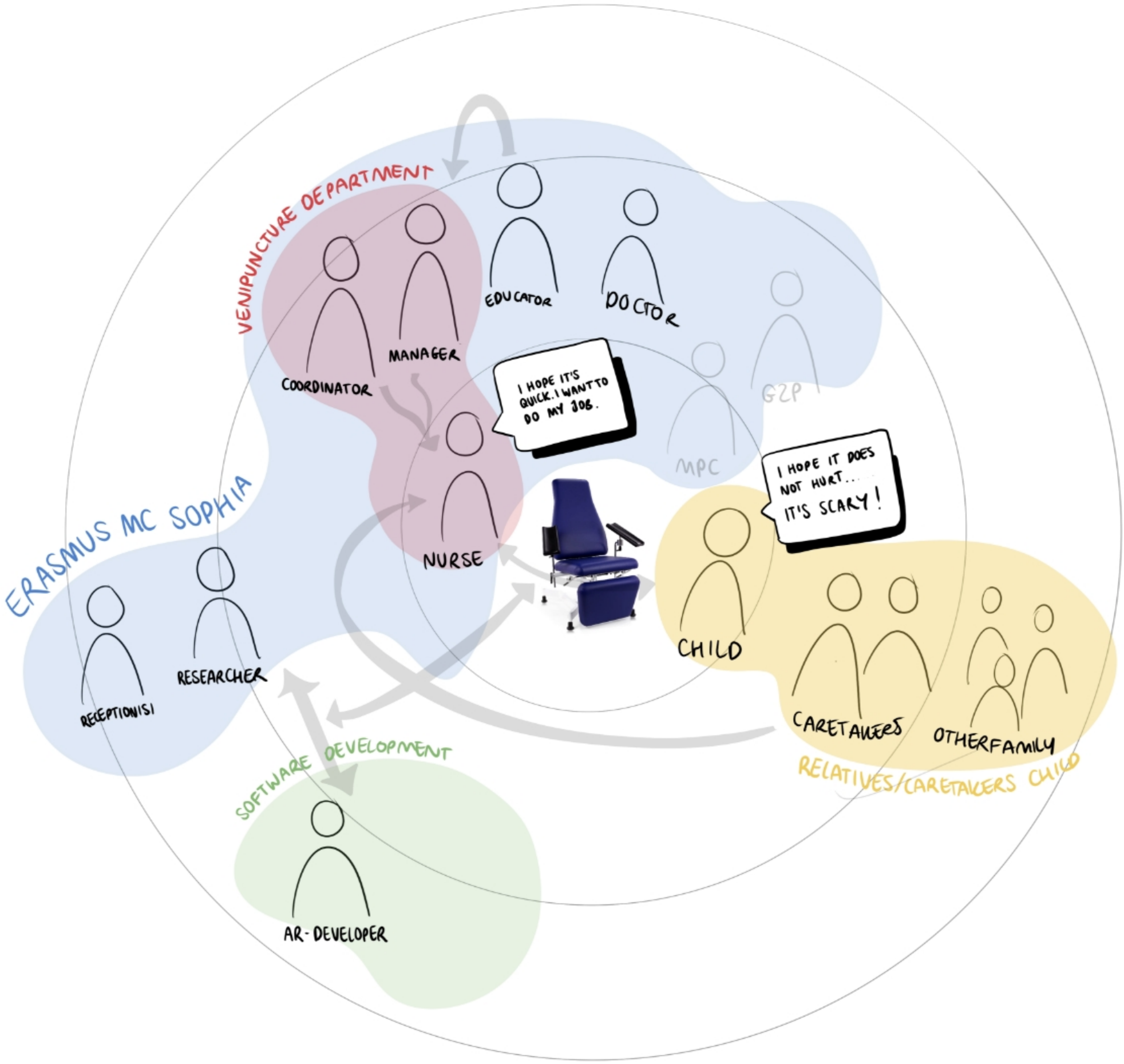


Figure 18. Stakeholder map/ecosystem for an AR venipuncture procedure with roles, relations, concerns and wishes.

Ex-patient, 23 years old

Personal story about blood draw

As a child, she spent a lot of time in the hospital and during the age 7-9 years she frequently had to undergo venipunction. At the time, she did not really understand what was happening and why. She would sometimes ask her father: "Dad, am I going to die?". She was very scared and the blood draw procedure was one of the very worst things that could happen in the hospital. It hurt a lot, but it felt like she was not taken seriously. It felt like was her versus the adults.

How could the procedure improve?

She missed a sense of control in the situation, the feeling of being able to choose. On beforehand, she would have liked to have a clear conversation with the doctor explaining her the procedure without words such as 'pain' and 'scared'. Also, her parents should have also been informed about their behaviour, to make her feel more relaxed instead of telling "I know it hurts". Never scare children on beforehand, distract them during the procedure with something fun and afterwards reward them with a little present to make sure the last memory they have of the blood draw is something good.

Figure 19. Interview with ex-patient who identifies herself as someone with a needle phobia, due to childhood trauma.

Nurse, 28 years old

Personal story about blood draw

It can be very crowded at the venipuncture department. Often, parents and children are in a hurry as they need to go to their next doctor's appointment and ask us "How long is it going to take?". But that is uncertain and fully dependent on the child. I have once waited for over 40 minutes until the child was ready for the procedure. I am patient, but I also have my limits and when I exceed those, I recommend the parents to visit the Medical Pedagogical Caretaker (MPC)

How could the procedure improve?

In order for the puncture to succeed, it is important that the patient sits still as much as possible. Preferably, the patient relaxes their muscles as much as possible. In terms of distraction tools, I don't have time to look at a tablet and puncture at the same time. I don't know why we are not using the distraction tools, it is just not in our system.

Figure 20. Interview with nurse who is responsible for executing the venipuncture procedure. The summary is actually a summary of three different nurses, each individual semi-structured conversation can be found in Appendix C.

Medical pedagogical caretaker, 50 years old

What is your responsibility at the venipuncture department?
I guide children that experience severe anxiety (and pain) during venipuncture procedures. I take the time to talk to children about their fears and the procedure itself. We set up a 'puncture plan' together to provide an overview on how they want to experience the venipuncture. Children 6-12 years are mature enough to explain their personal preferences. You should give them that feeling of control.

How could the procedure improve?
If fear would be detected at an early stage already, it is much more easy to get a grip on and coercion should never be used as that causes most trauma.

What do you think of AR as a distraction tool?
Might be better than VR, as children peek underneath the headset. Some kids want to see every bit of the procedure, so that might not be for them at all. It is for the category that do want to try a headset, but still have some form of control.

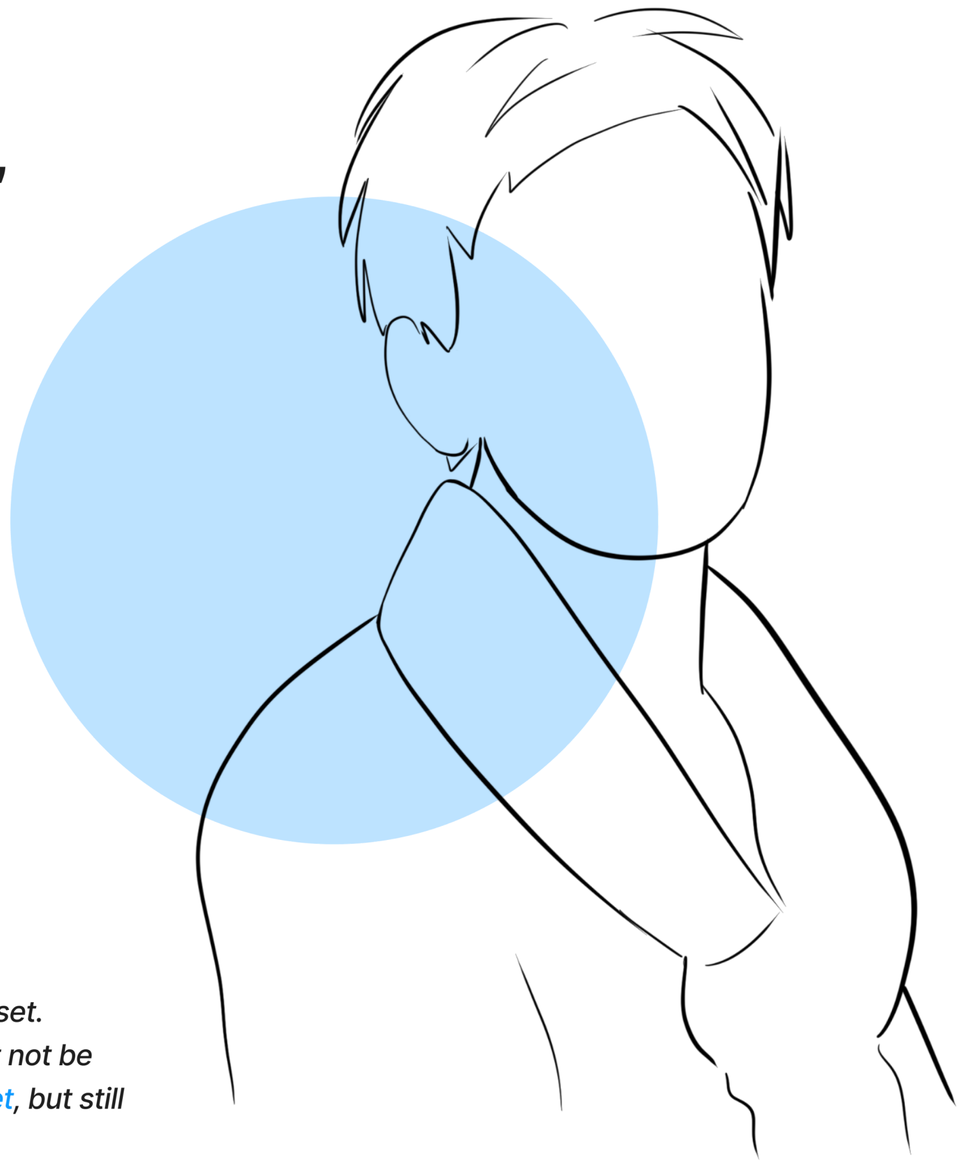


Figure 21. Interview summary with Medical Pedagogical Caretaker (MPC) who is responsible for guiding the child when anxiety levels are high.

There is an important relationship between the nurse and the child, as they both have their concerns that might sometimes contradict. It is a challenge to find a right balance between the two stakeholders's concerns. Figure 22 visualizes this balance.

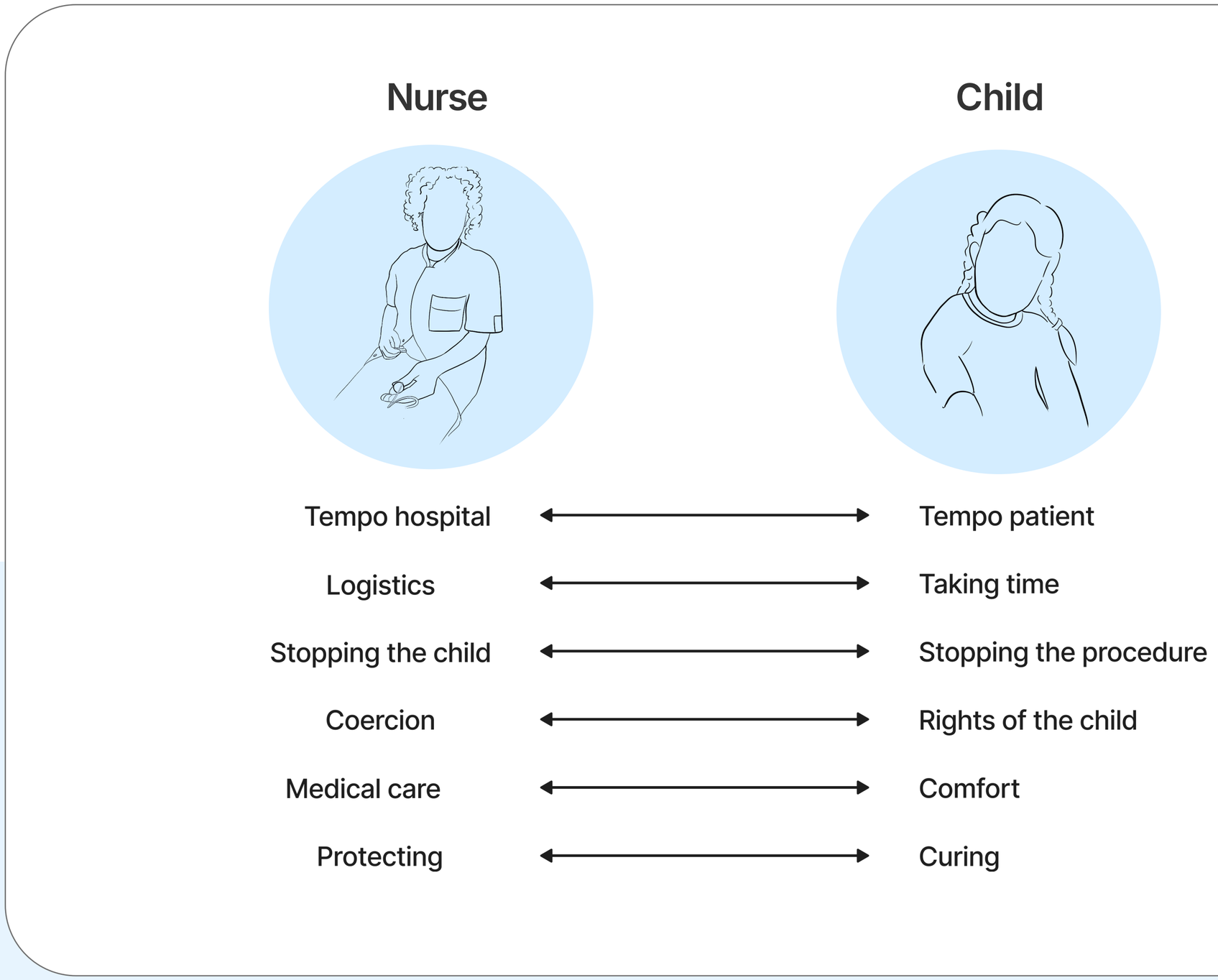


Figure 22. Visualisation of different concerns for the nurse versus the patient, based on the 'Omgaan met angst bij kinderen in het ziekenhuis - Afdeling Psychosociale zorg' lecture by Zirar (2024), used under CC BY.

1.6 Sense of being in control

How is a sense of being in control realised at the Sophia?

This chapter builds upon the Comfort Care approach in the Erasmus MC Sophia and uses literature from the pediatric caretaker lecture on Comfort Care (Afdeling Psychosociale Zorg, 2019) and interviews.

The patient cannot actually control the procedure, as the venipuncture must be performed for their health and well-being, regardless of their fear levels. However, through specific methods, it is possible to experience a sense of control, allowing the patient to feel more empowered and involved in the process. Current Methods Used by Nurses to Foster a Sense of Control Nurses at the venipuncture department already apply several strategies to provide children with a sense of agency during the procedure. These include:

1. Offering Choices
Giving the child the opportunity to make decisions helps them feel involved in the process. For example:

Choosing which arm they would like the procedure to be performed on.

Deciding whether they want to look at the procedure or look away. This is especially relevant for the AR intervention. If there is no choice of looking directly, a loss of control is experience. Allowing them to choose whether they would like the nurse to count down before inserting the needle.

2. Setting Up a Puncture Plan
For children experiencing higher levels of fear, nurses, together with the Medical Pedagogical Caretaker (MPC), may create a detailed puncture plan. This plan allows the child to express their preferences about how they would like the procedure to be carried out. By involving the child in this way, they feel that their concerns and wishes are taken seriously, which enhances trust and cooperation.

These tricks can significantly reduce anxiety because when children perceive that they have some influence over what is happening to them, they are more likely to feel calm and cooperative. In the context of venipuncture, fostering this sense of control can improve the overall experience for the child and contribute to the success of the procedure.

3. The Role of Positive Language
In addition to providing choices, nurses often use positive and encouraging language to promote a sense of control and calmness. This approach shifts the focus from fear and discomfort to empowerment and achievement. For example:

Instead of saying, “Try to keep still,” a nurse might say, “I am curious to find out how still you can keep?”

This phrasing frames the action as a (fun) challenge or goal rather than an instruction, encouraging children to feel pride in their cooperation.

Using gentle, reassuring words that avoid terms like “pain” or “scared” further reduces anxiety and fosters a supportive environment.

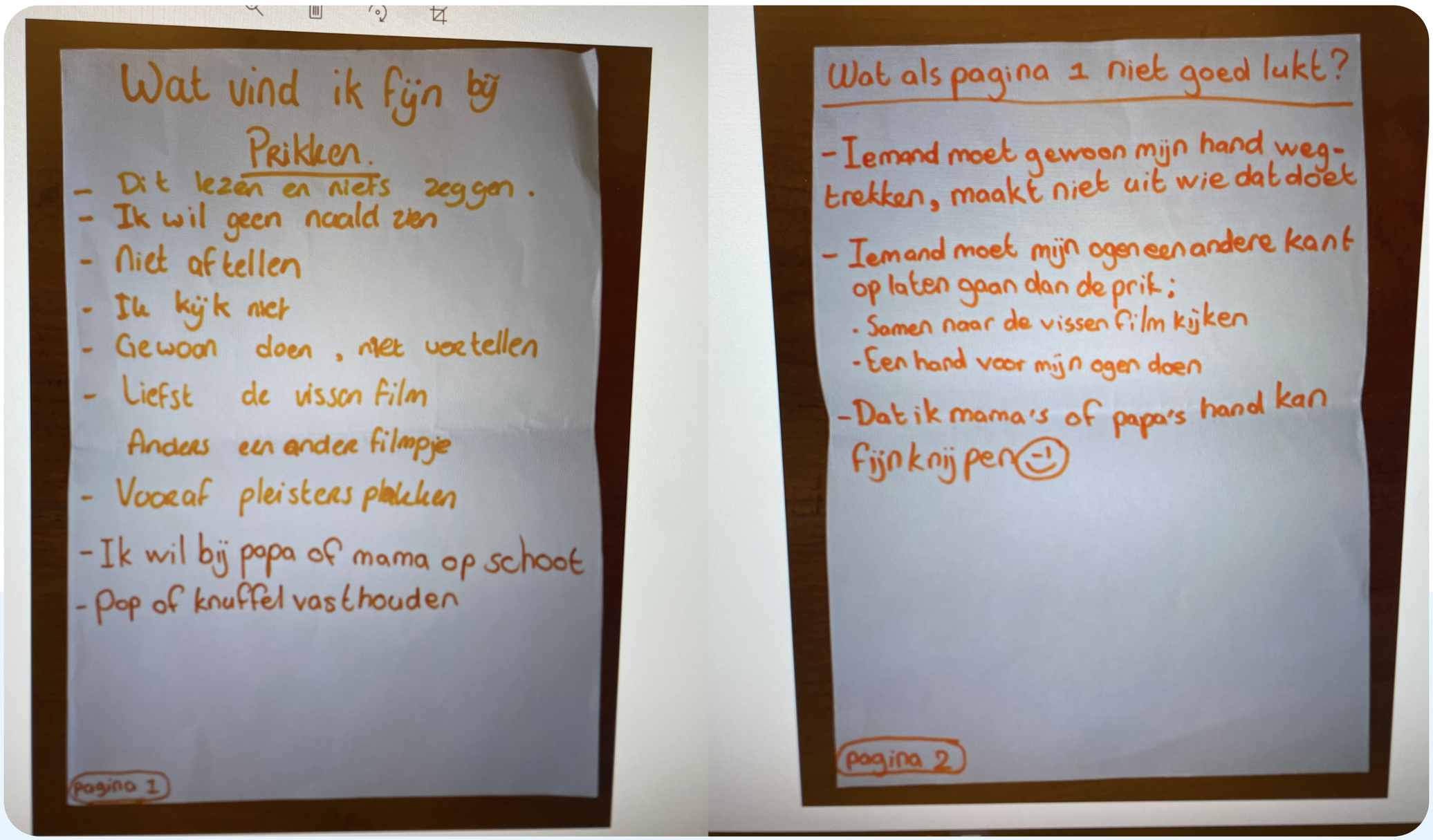


Figure 23. A puncture plan made by an eight year old girl.

1.7 Potential of AR

What are the possibilities and limitations?

This chapter explores the potential of Augmented Reality (AR) within the short-term scope, examining what is currently possible with existing technologies and how AR can be applied in the context of a hospital setting.

Possibilities
One of the reasons the Medical Pedagogical Caretaker (MPC) is involved in the current VR venipuncture experience is that VR immerses the child completely, preventing interaction with the real world. Observations have shown that, during a VR session, the child primarily interacts with the MPC and not with the nurse. As noted by Bruno et al. (2022), "VR should always enhance the real-world provider-patient relationship and should not be a tool to replace it." This is where AR can offer a significant advantage. AR allows children to still interact with their real environment, while simultaneously overlaying digital elements, through the use of AR video pass-through (Figure 24). This interaction with the physical world can help maintain a connection with reality, potentially reducing the need for constant guidance and allowing the child to feel more independent during the procedure.
Figure 25 shows what the Meta Quest 3 is capable of and the aspects that will potentially be used for developing the prototype.

Limitations
Despite its potential, there are limitations to using AR that must be carefully considered. AR may, like VR, induce unwanted side effects, such as headaches, nausea, and vomiting, collectively referred to as "cybersickness." (Bruno et al., 2022). These effects could limit the applicability of AR in medical settings, especially for children who may already be experiencing discomfort due to the procedure itself. Therefore, it is crucial that any AR experience is designed with careful consideration to prevent additional physical or emotional distress for the child.
The effectiveness of AR can vary depending on the technology used. Not all children may respond positively to digital overlays, and there is the possibility that the distraction may create confusion or add to the child's anxiety, rather than minimizing it. Furthermore, the implementation of AR in a medical environment would require appropriate training for healthcare staff. Nurses and other medical professionals need to understand how to use the technology effectively without disrupting existing care practices or compromising patient safety.

Figure 24. The mixed reality headset Meta Quest 3 with a digital layer projected on top of the real world (Meta, 2023).

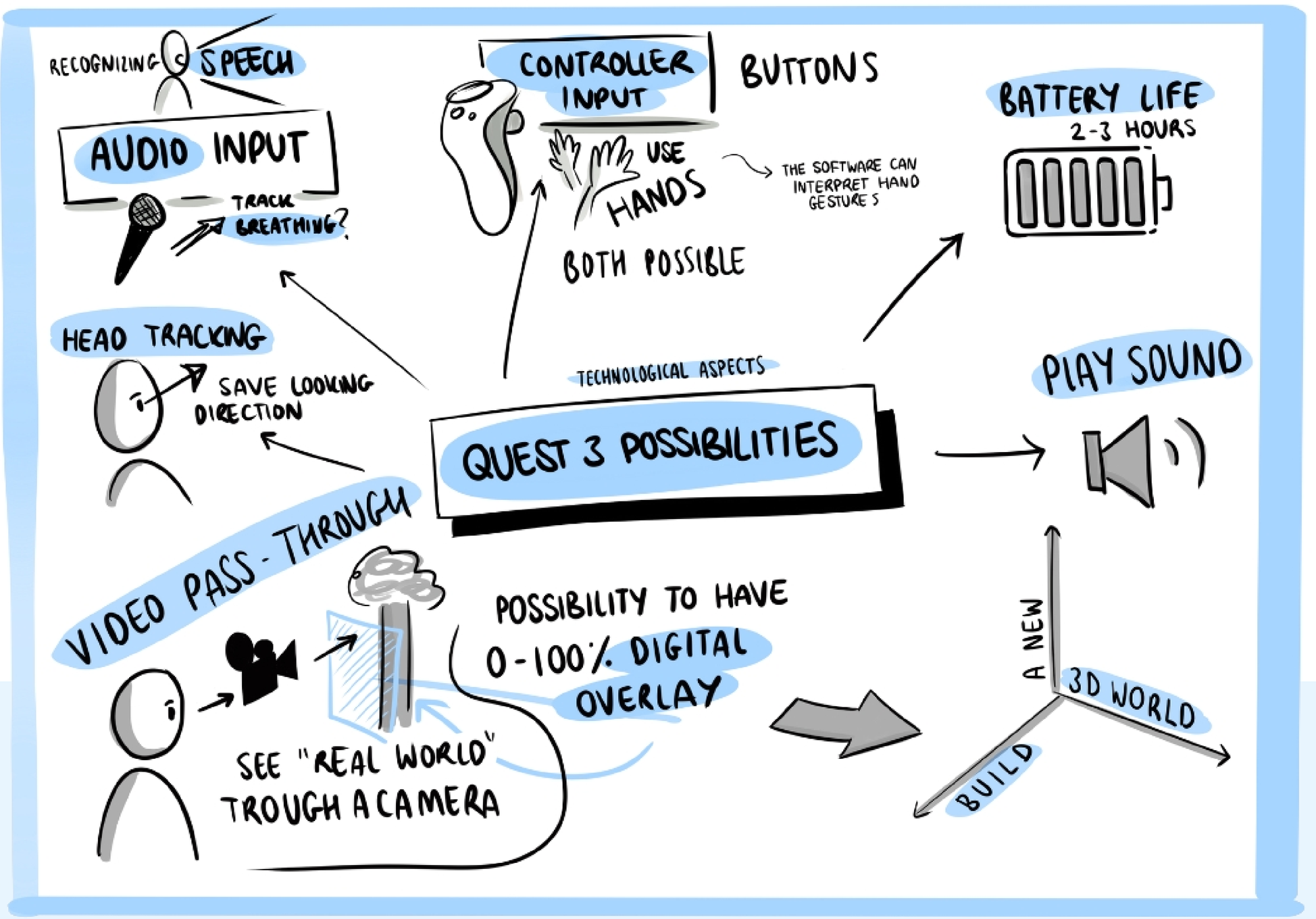


Figure 25. An overview of what the technological possibilities for the Meta Quest 3 are.

1.8 Target group

What captures attention for the target group?

The target age group for the AR intervention is children aged 6 to 12 years, spanning two distinct developmental stages. Understanding the cognitive and emotional abilities of children within this age range is key to defining an effective design. As shown in Figure 26, which draws on Piaget's Theory of Cognitive and Social-Emotional Development (Simply Psychology, 2024), children transition from the Preoperational Stage (ages 2–7) to the Concrete Operational Stage (ages 7–11).

Preoperational Stage (Ages 2–7)
Younger children in this stage think symbolically and are heavily influenced by imagination. Fantasy plays a significant role in their understanding of the world.

Concrete Operational Stage (Ages 7–11)
As children enter this stage, they begin to apply logical reasoning to their experiences. Their thinking becomes more concrete, and they are more drawn to facts. For example, while younger children may firmly believe in figures like Santa Claus or Sinterklaas, children around ages 8 or 9 begin to question these beliefs as their reasoning abilities develop. While imagination still plays a role, logical thought starts to dominate.

Overlapping Trends for 6–12 Year-Olds
While there are notable differences in the individual interests of children aged 6 to 12, certain overlapping themes emerge. As illustrated in Figure 26, these include: nature and animals/wildlife, superheroes, arts and crafts, sports, music, adventure and puzzling.

Another big trend is gaming. The vast popularity of games like Roblox—with over 32.4 million users under the age of 13 (Singh, 2024)—shows how deeply screen-based interactions have become integrated into children's lives. Roblox, in particular, is considered as an extremely addictive and popular game among children (Meulenkamp, personal communication, 2024). This insight into children's affinity for interactive, screen-based entertainment is valuable when considering the design of an AR experience that will appeal to this age group.

By aligning the design of the AR experience with these common interests, the final product can resonate with a broad spectrum of children within this age group, making it more engaging and effective as a distraction tool during medical procedures like venipuncture.

For the design, it would be thus valuable to have a **layered approach**: a specific theme that sparks interest on a fantasy level, but also on a cognitive thinking level.

Game design values

To measure whether a theme would be succeeding for children, the following game design values will be taken into account (Kultima et al., 2016):

1. **Engagement and Immersion**
   Making the player feel connected to the game world.

2. **Fun and Playfulness**
   Ensuring enjoyment through interaction and exploration.

3. **Accessibility and Inclusivity**
   Designing for diverse players and abilities.

4. **Challenge and Mastery**
   Offering opportunities for skill development and achievement.

5. **Narrative and Meaning**
   Creating an emotional connection through story.

6. **Innovation**
   Pushing creative boundaries with mechanics or visuals, the experience should be something new.

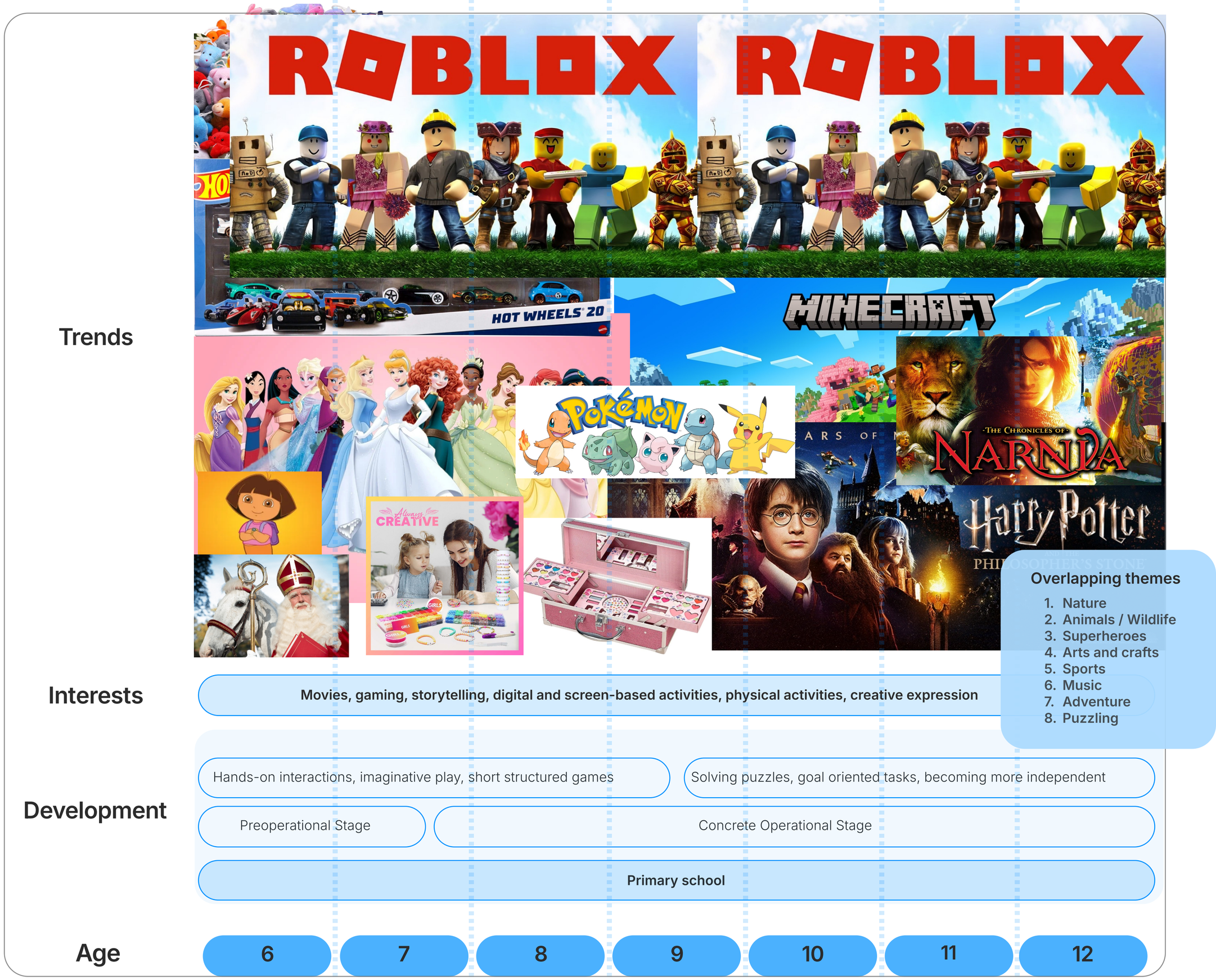


Figure 26. Child development for children aged 6-12 years old, with relevant interests, matching with today's trends, based on Piaget's 'Theory of cognitive development' .

1.9 Conclusion

What conclusions can be drawn through answering the research questions?

During the Discover phase, valuable insights were obtained through combining theory with practice, contributing to answering the research questions.

Q1.2: How does distraction influence pain and anxiety?
Literature showed that distraction methods are proven to minimize pain and anxiety during venipuncture, with **active distraction** (playing a game, cognitive task) being more effective than passive. Shifting focus away from the procedure happens through arousing curiosity, desensitizing, capturing attention, interactive learning and connecting relationally.
Distraction methods work best if other measures for pain and anxiety are taken:

Pain
> Use anesthetic cream to reduce pain
> Reduce prediction of pain (reduce nocebo)

Anxiety
> Explain clearly what to expect of the procedure expectation management
> Professional help with negative prior experience
> Positive use of language

Q1.3: What do venipuncture procedures look like in the Sophia?
Venipuncture procedures at the Sophia follow a systematic process that was mainly analysed through observations and interviewing. The following conclusions were made:

Personal coping mechanisms for patients
It is important to allow for very different styles of coping for patients during the procedure, e.g. from looking, to not looking at all. This emphasises the need for a personalised approach in the AR experience.

Influence of nurses and parents/caretakers
Nurses and parents/caretakers can have a calming effect on the procedure for the child due to rewards they give and positive reinforcement. On the contrary, when negative influence occurs (such as hurriedness caused by parents/caretakers) the procedure becomes very stressful for the nurse and child.

Puncture room environment
The room's environment plays a significant role: rooms that were lacking child-appropriate decorations or comforting elements were associated with higher stress levels.

From the patient scenario and the patient journey map, main findings were:
The unpleasant waiting room
This is a very negative experience where tension rises. After talking to experts, it was clear that there could be a design intervention here already.

Variance in empathy from nurses
A discrepancy in empathy is present. Some nurses detect anxiety at an early stage already and take it into account when interacting with the child, where others are less concerned with it and perform equal treatment for every patient.

Post-procedure interaction
The final interaction after the procedure has a lasting impact on the child's overall perception. A positive closing experience, such as offering a compliment or small reward, can significantly improve their mood and confidence.

Q1.4 What are current effective (distraction) methods?
From analysing existing distraction tools, key elements were formulated that are proven to be effective for distraction:
Engaging Tasks, Breathing Exercises, Bright, Vibrant Colors and a Multisensory Experience.
Tools that engage additional senses, such as vibrations (e.g., Buzzy) or temperature variations (e.g., heat/cold packs), enhance the distraction effect.
However, the tools from the distraction tool box are hardly ever used as nurses do not have the use of them implemented in their routine.

Q1.5 Who is involved and what are their concerns?
The most important stakeholders during a venipuncture procedure are the nurse and the patient. Their concerns differ and can sometimes even be on opposite extremes. Such as that the child needs their time for the procedure, but the nurse would preferably have it executed as quickly as possible.

Patient/child
Scared of the venipuncture: the most painful and scary procedure in the hospital.
Especially anxiety with prior negative experience, this can be very deeply rooted.
Feeling like they are not in control
Feeling like it is them against the adults
Not understanding why exactly it is happening

Nurses
Experiencing time pressure
Crucial for the patient to stay calm, sit still and relax muscles
Trying to address the child's and caregiver's anxiety while managing procedural responsibilities

Q1.6 How can a sense of control be realised?
The patient cannot actually control the procedure, as the venipuncture must be performed for their health and well-being. However, a sense of control during venipuncture can be realized through methods that empower and involve the patient, particularly children. Drawing from the Comfort Care approach and existing literature, the strategies include:

Offering Choices: nurses involve children by allowing them to make decisions, such as selecting the arm for the procedure, **deciding whether to watch or look away** (especially relevant for AR: if there is no choice of looking directly, a loss of control is experienced) or choosing if they want a countdown before the needle is inserted.

Creating a Puncture Plan: For children with high levels of fear, nurses collaborate with a Medical Pedagogical Caretaker to create a plan that incorporates the child's preferences, building trust and cooperation.

Using Positive Language: Nurses use encouraging and gentle language to frame venipuncture instructions as challenges or achievements instead of 'orders', avoiding words that evoke fear or pain.

Q1.7 What are AR's possibilities and limitations?
Possibilities of AR
AR has the possibility of still staying connected to the real world and staying grounded with physical surroundings, but with a digital layer of fantasy on top of it
The Meta Quest 3 allows for displaying a 3D world/objects on top of the physical world, playing (spatial) audio, tracking head movement, hand/speech/controller input and even speech recognition.

Limitations of AR
AR can cause cybersickness
AR could block the interaction between the nurse and patient
Requires extra training for nurses
The headset needs to be well prepared (charged, fitting around the patient's head)

Q1.8 What captures attention for the target group?
The target group varies between 6 and 12 years old, this means that children are in very different development phases. Children are shifting from imaginative thinking to cognitive (logical) thinking, which asks for a different approach in engaging exercises as specific interests and beliefs can change rapidly. It is necessary to use a theme that attracts the entire age group, with a layered approach that is appealing to both ways of thinking, whilst taking into account game design values for optimal effect.

2

Define

The Define chapter translates research insights into actionable design directions. This chapter identifies the key challenges and opportunities, introduces archetypes representing different coping styles, and establishes clear interaction boundaries. It also formulates a design goal and interaction vision, setting the stage for ideation and development. By the end of this chapter, the design requirements are clearly listed, serving as boundaries and guidelines for the creative process.

2.1 Challenges and opportunities

What challenges and opportunities for the design can be identified?

Challenges

1. Diverse patient needs
Different coping mechanisms: each child has a personal coping style during the procedure and has a personal preference for what feels comfortable
Wide age range: the target group (6–12 years old) spans different developmental stages, making it challenging to design AR experiences that are appealing to all ages.
Pre-existing anxiety: deeply rooted anxiety, especially from prior negative experiences, is difficult to fully address with AR alone.

2. Stakeholder Conflicts
Opposing goals: nurses prioritize efficiency, while children need time to process their emotions and feel empowered.

3. Integrating seamlessly with a medical workflow
Currently, distraction tools are rarely used because they are not embedded into routine practices. It is a challenge to design AR in a way that seamlessly integrates into the medical workflow, making it easy and intuitive for nurses to use. This integration will require additional training for nurses.

4. AR Limitations
Cybersickness: ensuring AR experiences do not cause discomfort is critical, particularly for anxious children.
Interaction interference: AR might disrupt the relational connection between nurses and patients.
Equipment readiness: Ensuring AR devices are charged, properly fitted, and functional could add logistical complexity.

Opportunities

1. Innovative distraction method
AR is a unique distraction tool with its 360-degree view and spatial audio, creating a fully immersive audiovisual experience that is not possible with traditional methods (e.g. books, phones).
Combination of effective elements: AR can combine proven techniques from other tools, such as vibrant colors, engaging tasks, and multisensory elements (e.g., vibrations, sounds), to effectively distract and reduce anxiety.

2. Control over the environment, independence from physical facilities
AR can provide a new opportunity for rooms lacking child-appropriate decorations, as it can enrich existing puncture rooms with a digital fantasy layer → ensuring child-friendly environments regardless of the room's physical condition.

3. Positive reinforcement, independence of negative influences
AR remains a constant positive element, free from the stress or negativity that may arise from nurses, parents/caretakers or other factors. Positive reinforcement can be incorporated throughout, using encouraging language and a supportive tone.

4. Waiting room experience
Pre-procedure calming: The waiting time can be used to calm and distract the child, reducing their stress level before entering the puncture room.
Expectation management: AR in the waiting room can help set realistic expectations, reduce fear, and counteract the nocebo effect.
Distraction during waiting: tensions that might occur in the waiting room can be avoided, such as hearing other children scream and cry.

5. Technological potential
The AR technology allows for displaying 3D worlds or objects overlaid on the physical environment, playing (spatial) audio, tracking head movement, hand/speech/controller input and even speech recognition.

6. Interactive possibilities
AR provides possibilities for interactive engagement with feedback, such as interactive games.

7. Sense of control
Through the pass-through option of AR, a sense of control is maintained by always offering the opportunity of looking directly without hiding the procedure. There is thus freedom of what to look at for the patient.

8. Minimize average procedure time
A well-designed AR tool can reduce the time required for venipuncture procedures by:
Allowing nurses to spend less time on comforting the child
Reducing the time spent on using distraction methods that require input from the nurse
Assisting nurses with venipuncture instructions

AI-generated image depicting 'child with VR headset'. Created with DeepAI, 2024.

2.2 Archetypes and control

What does a sense of control mean per patient?

As stated in the Discover phase, every child has their personal preference for how to cope with the procedure. However, it is impossible to design for every child individually. Therefore, three key archetypes were stated based on level of procedure involvement, see Figure 27. Along this spectrum, there is: the Monitor, the Blunter, and the Curious. Each archetype represents a unique coping style and degree of engagement, ranging from intense observation to complete avoidance, serving as meaningful design features for the AR experience. The ability to choose this level of involvement ensures a sense of control.

The Blunter is the least involved in the procedure, actively seeking to disengage and avoid the experience. This child copes by redirecting their focus away from the procedure entirely, often through external distractions. For the Blunter, an AR design that provides immersive, captivating distractions aligns well with their need to distance themselves, helping to reduce anxiety by minimizing awareness of the procedure.

The Curious prefers a moderate level of involvement, expressing a desire to understand what's happening without needing to monitor every detail. This archetype finds reassurance in explanations and enjoys learning about the process. An AR experience that includes gentle, informative elements can turn the procedure into a learning moment for the Curious, reducing fear through understanding.

The Monitor is highly engaged, observing every step closely as a means of maintaining control. This archetype's focus on the procedure can help them feel prepared, though it may increase anxiety if discomfort is anticipated. Designing for the Monitor involves incorporating calming features that allow them to stay informed while reducing stress.

Figure 28 indicates the most important viewing directions for the three key archetypes. It is important to take into account these preferences when designing the AR experience.

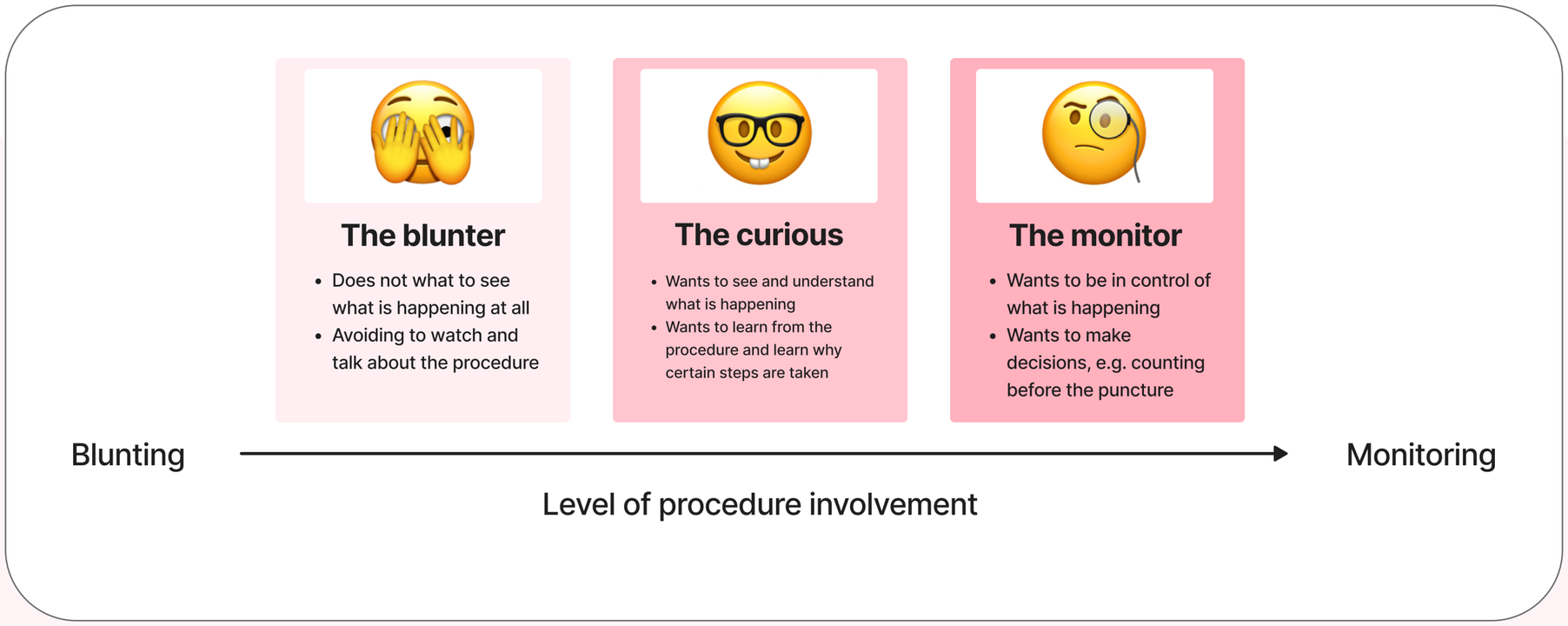


Figure 27. Different archetypes to design for.

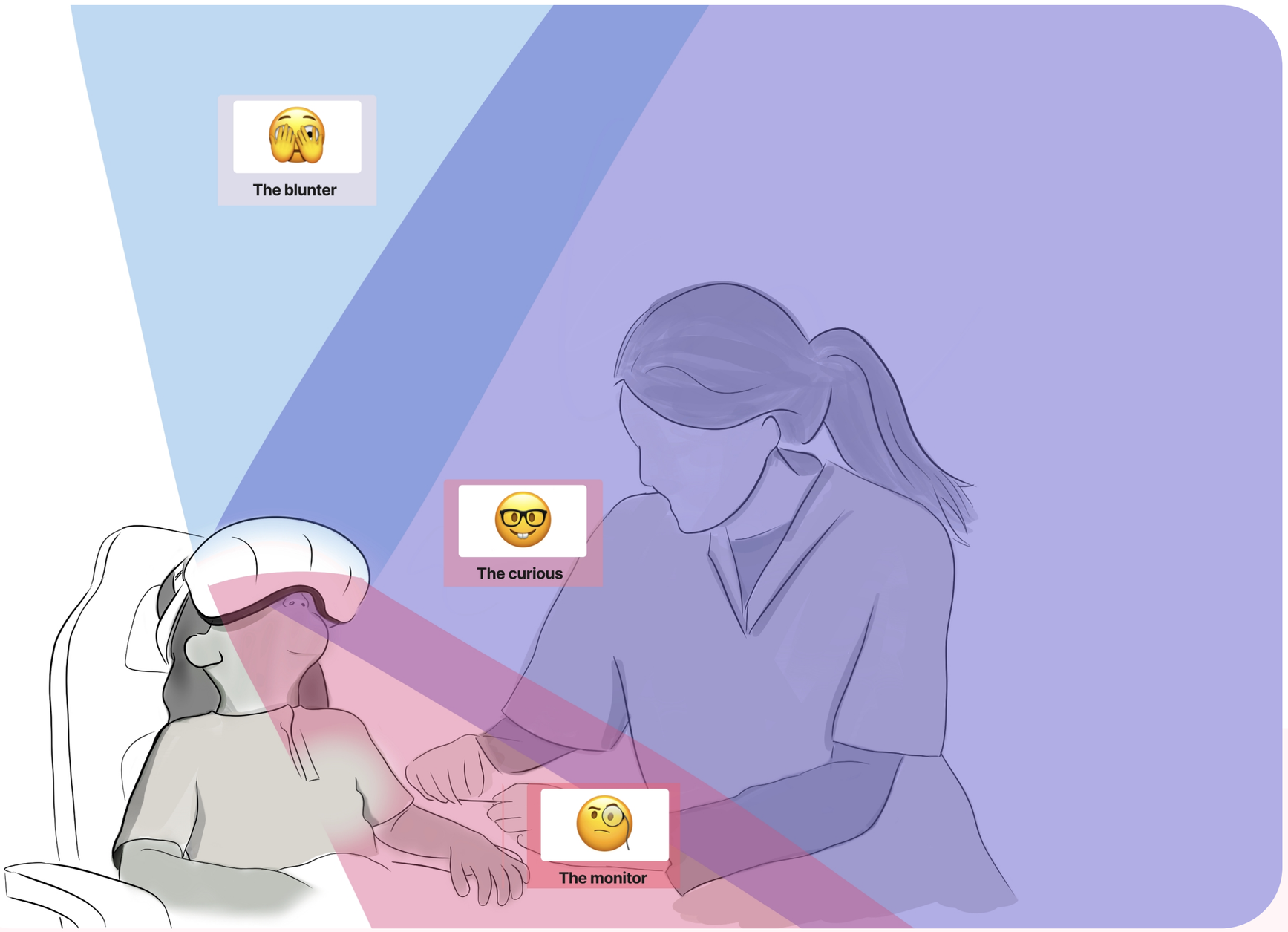


Figure 28. Outlined suggested viewing directions for key archetypes. This figure was created to visualize possible different interaction areas per archetype.

2.3 Defining interaction boundaries

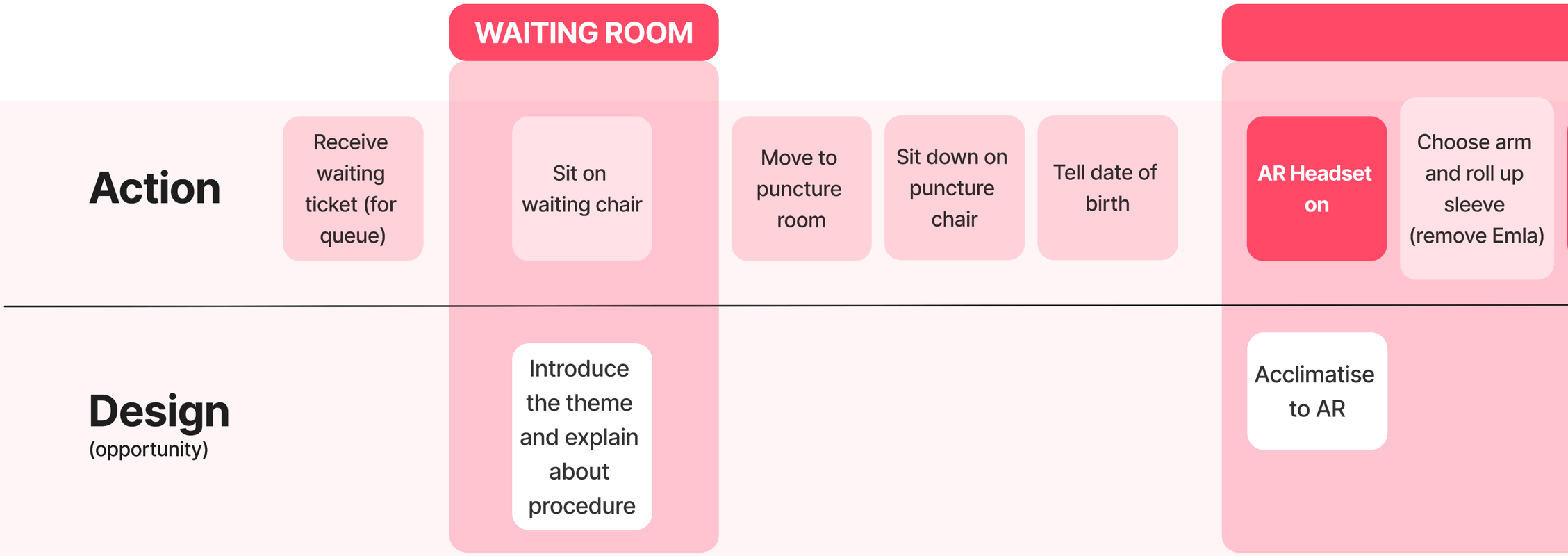
What is the design scope for the AR experience within the venipuncture process timeline?

This section examines the appropriate scope and timing of the AR experience within the venipuncture process: when should the AR experience begin, and when should it end? While the primary goal is to provide distraction during the puncture itself, research from the Discover phase suggests that extending the experience to pre-procedure (waiting room) and post-procedure (physical souvenir) moments may enhance the AR experience's effectiveness. However, according to the client, the AR headset is only available in the puncture room and cannot be used in the waiting room. Therefore, the pre- and post-procedure experiences will be conceptually explored in the Develop chapter, but testing and evaluating will remain focused on the in-procedure AR Experience. Figure 29 shows the different experiences over the venipuncture process timeline.

1. Waiting room experience (pre-procedure)
This experience begins once the patient receives their waiting ticket. Since waiting times vary from a few minutes to over half an hour, the experience must be flexible and easily interruptible at any moment, allowing for seamless transitions when the child is called in for the procedure.

2. AR Experience (in-procedure)
This is the core focus of the project. Essential design considerations include incorporating a brief acclimatization phase, guiding attention away from the procedure, and integrating a breathing exercise to support relaxation. The exact duration of this experience varies significantly per patient, ranging from a minimum of two minutes to even over an hour in most extreme cases.

3. Souvenir (post-procedure)
Following the procedure, children typically receive a small reward as part of standard care. This is a small physical present they can choose from, and often they receive a compliment. Ending the AR experience on a positive note can reinforce a sense of accomplishment and help reframe the venipuncture as a less negative experience. A well-designed physical souvenir could enhance this moment and provide lasting positive reinforcement.



Duration and Interruptibility
The duration of the waiting room and in-procedure AR experience should be flexible, considering their duration is ranging from 1 to 60 minutes. Moreover, the interaction must be interruptible at any moment, ensuring that unexpected real-world events always take priority. The AR experience should be adaptive, allowing users to transition in and out of the experience without disruption to the procedure itself.

Conclusion
As highlighted in the research phase, an enhanced waiting room experience and a meaningful physical souvenir could strengthen the overall AR experience. However, due to the scope limitations of this thesis and its primary research objective, the focus remains on the in-procedure AR experience. The pre- and post-procedure components will be conceptually explored in the Develop chapter, but will not be tested or validated within this project.

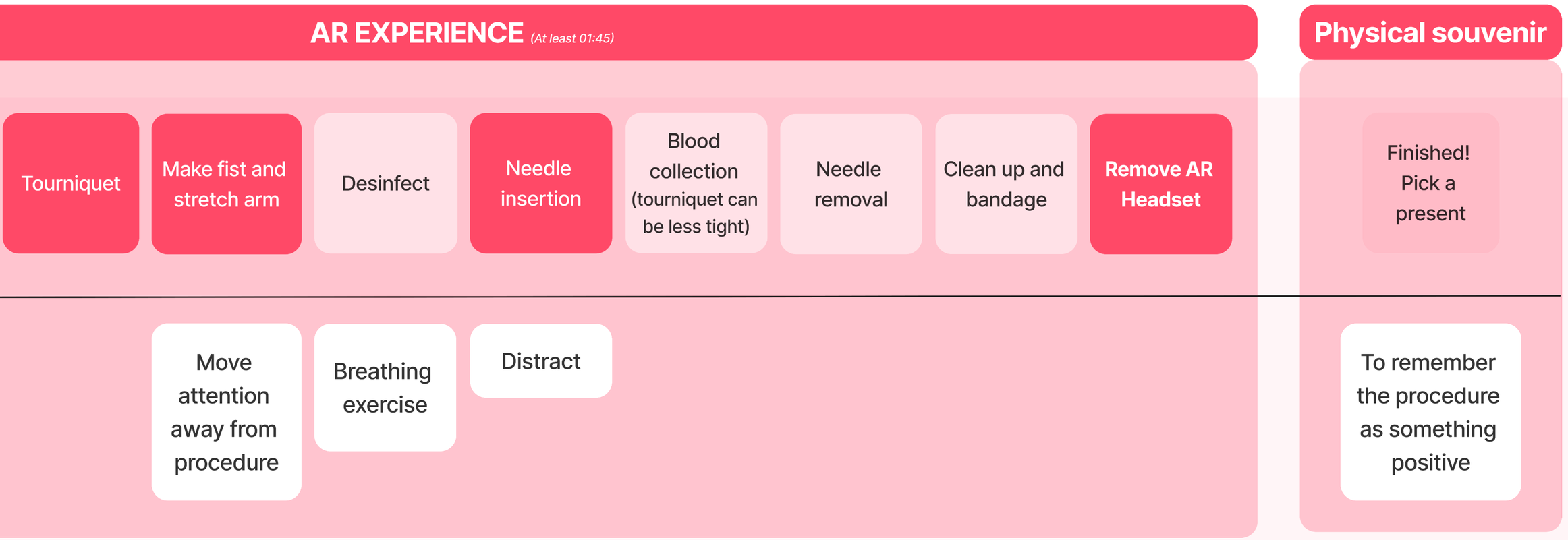


Figure 29. Mapping out all the steps of a venipuncture procedure and identifying the boundaries of the to be designed experience.

2.4 Design goal

How is a direction for the design process realised?

In order to provide a direction to design towards, a design goal was formulated. The iterations of the design goal can be found in Appendix D.

To create a **distracting** and **calming (AR) experience** for

children during venipuncture,

guiding their attention to an **engaging digital world**,

without hiding the physical procedure,

in a way that **improves the procedure experience** for both the

child and the nurse,

while being **easy to implement** in a **clinical workflow**.

Design goal elements

Distracting and calming
These aspects help best with reducing pain and anxiety.

(AR) Experience
The main experience is Augmented Reality, but the waiting room experience not. The goal is to create something greater than just the AR experience.

Children
The target group of 6-12 years with fear for puncture.

Guiding attention
Luring attention towards the digital world.

Engaging digital world
The world is appealing and engaging for children.

Without hiding the physical procedure
The real, physical procedure will be shown in the digital world.

Improving procedure experience
The goal is that the design will improve procedure experience for both the child and nurse.

Easy to implement
The majority of the ideas fail on implementation. As suggested by the client, this should definitely be in the design goal.

Clinical workflow
It is important to keep in mind the clinical workflow of the hospital.

2.5 Interaction vision

What should the desired interaction feel like?

To conceptualise the interaction with the experience, an analogy-based approach was used: the Interaction Vision (van Boeijen et al., 2014) . This method enabled to derive specific interaction qualities, which in turn serve as inspiration for the final design. Different ideas and brainstorms for the Interaction Vision, can be found in Appendix E.

The chosen metaphor is 'Head in the clouds'. This is derived from its figural meaning: to be drifting away in thoughts, **daydreaming** so to say. The feeling of **forgetting the real world**, and wandering off in a **pleasant fantasy place**. For venipuncture this means forgetting about the tough procedure pain and focussing on a better fantasy world.

Interaction qualities are:

- The interaction feels light and easy
- The interaction is relaxing/soothing
- The interaction feels like dreaming, which means there is room for imagination
- The interaction feels soft as the clouds

The interaction should feel like having your head in the clouds. Drifting away with your thoughts and wandering off to a pleasant fantasy place.

Figure 30. Interaction visual: head in the clouds.

2.6 Requirements and wishes

What must the design accomplish?

To provide guidelines during the design process and as a measure for the final prototype, a list of requirements and wishes was determined from the obtained data in the Research and Define phase. The 'List of Requirements' is a design method used to define the mandatory criteria that the final design must meet (Roozenburg and Eekels, 1989). Requirements are hard rules that the design must follow, while wishes are desirable features that would improve the design but are not essential for the design to function. Wishes are formulated to function as evaluation criteria during decision-making in the develop phase.

General experience

1. Any content of the experience meets guidelines for responsible content for children's media from the age of at least 6 years old as indicated by Kijkwijzer (Kijkwijzer, n.d.).
2. The content and appearance of the experience is suitable for children aged 6 to 12 years old, taking into account their cognitive and emotional development stage.
3. Information in the experience is approved by medical professionals if related to medical context.
4. The experience is distracting enough (within a hospital context) to minimize pain and anxiety.

Usability

5. The experience is standalone and does not require external help from a health care professional, apart from mounting the headset.
6. The experience requires no arm movement during venipuncture.
7. The playtime of the (AR) experience is flexible, allowing for interruption at any moment and also without a specific end time.
8. The experience functions on a default setting that does not require any extra settings, with a less is more mentality.
9. Use of the experience is also possible without reading skills.

Language and tone

10. The tone of the experience is positive, rewarding and uses positive language (avoiding difficult words and words that trigger negative emotions).
11. The language in the experience is appropriate for children 6-12 years.
12. The experience is intuitive and does not require a tutorial for the user.

AR Experience (during venipuncture)

13. The audio of the experience does not overrule the voice of the nurse.
14. The experience allows the child to choose their level of procedural involvement, reaching from full involvement to no involvement at all, maintaining their sense of control on where they would want to look at.
15. The AR experience is standalone, meaning it can be understood without the prior waiting room

*Waiting Room Experience (pre-procedure)

16. The waiting room experience is low-threshold and easily accessible, meaning no necessity for gathering extra materials by the user.
17. The experience distracts from the tension build-up in the waiting room.
18. The experience is interruptible at any moment.
19. The experience does not hinder other people in the waiting room.

*Souvenir (post-procedure)

20. The souvenir is a reinforcing reward for the child to maintain a positive memory of the procedure.

Technology

21. The AR experience should operate continuously for at least 2–3 hours on a single charge, covering multiple venipuncture sessions.

22. The technological aspects of the design are realistic to implement on a short-term basis, by using current technologies available (for AR hardware and software).

23. The AR experience must be compatible with standalone AR/VR headsets that support video pass-through and hand tracking, including (but not limited to) the Meta Quest 3 and Pico 4.

Implementation and scalability

24. The AR experience is easy to implement as it does not hinder the workflow of the nurses.

Health and safety

25. The experience complies with health and safety regulations for medical devices (from the hospital) and AR applications (provided by Meta, 2024), ensuring user safety at all times.

26. The AR experience should be designed for an optimal session length of up to 10 minutes to minimize the risk of discomfort (e.g., dizziness or headaches), as recommended by VR experts. However, the experience should remain adaptable to accommodate venipuncture procedures that last longer than that.

*The primary focus of this project is on the AR Experience during the venipuncture procedure, but there are also requirements set for the Waiting Room Experience (pre-procedure) and the Souvenir (post-procedure). These will not be evaluated but serve as guidelines.

List of Wishes

1. The experience should invite or challenge the patient to sit as still as possible.

2. The experience should calm and release tension in the muscles.

3. The experience should have an engaging storyline that can be layered for different ages.

4. The experience should venipuncture into something positive.

5. The experience should give children confidence about venipuncture, making them feel empowered and independent.

6. The design should be easily scalable for further expansion to other age groups or medical procedures, allowing for additional features in future implementations.

7. The design should be visually appealing and aesthetically pleasing.

3

Develop

The Develop chapter documents the creative journey to achieve the design goal. To guide this process, the design goal was dissected into four themes. Each theme contains key features, also known as building blocks for the final design. Key features were identified from data from the Discover chapter, Define chapter and from design methods in the Develop chapter.

The key features served as starting points for ideation, leading to different concept ideas. One concept theme was chosen using a weighted objectives method and client feedback. This concept theme was developed in Unreal Engine through multiple iterations, prototypes and pilot testing. Then, the final AR experience is presented. This design contains design elements that originated from the key features in this chapter. To evaluate the effectiveness of the design elements, a final AR prototype was developed. The limitations of this prototype are identified in the same chapter. The next chapters evaluate the prototype with the target group and healthcare professionals. The insights gained from this testing phase were analyzed and transformed into actionable improvements, which, along with the evaluated design elements, are described in the next chapter.

3.1 Design process

What steps were taken to reach the final design?

3.1 Design process
Although the design process was iterative and non-linear, this section offers a structured overview for understanding the process and its steps. Figure 31 outlines these steps and their relation to the corresponding chapter numbers. Each chapter number is briefly shed to light.

3.2 Identifying themes
As illustrated in the design process visualization, the starting point was the design goal established in the Define chapter. To address the various facets of this goal, it was dissected into four themes:

1. Distracting and calming
2. Sense of control
3. Procedure experience
4. Implementation

3.3 Design methods for distracting and calming
The theme “Distracting and calming” was central to the main research question and the design goal. Before fully defining the key features of this theme, various design methods were employed alongside data from previous research.

3.4 Identifying key features
By synthesizing data from earlier chapters, key features were identified for each theme. These key features served as building blocks for the ideation phase, guiding the conceptual direction and ensuring alignment with the design goal.

3.5 Ideation and concept direction
The ideation phase produced multiple concepts, and the most promising one was selected from a client feedback session and using a weighted objectives method that incorporated the list of wishes.

3.6 Prototype building
Prototype development occurred through several iterations, with ongoing testing among peers and refinement through input from AR experts. Although Figure 31 simplifies the process by presenting it as a single phase, these iterations were an ongoing aspect of the design process. This approach supported a continuous learning curve, allowing both the design and the AR development expertise to evolve throughout the project. The different iterations led to a final prototype.

3.7 Pre- and post-procedure experience
After the final prototype was built, an exploration was done on the pre-procedure (waiting room) and post-procedure (souvenir) experience, both were also evaluated with the client.

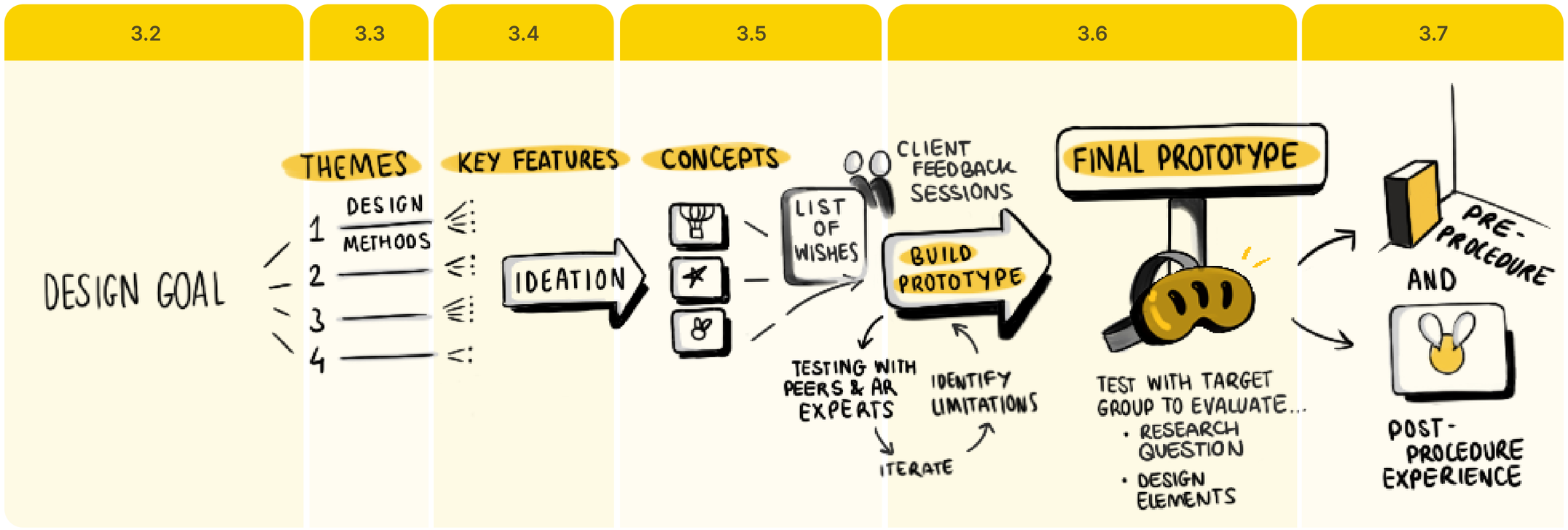


Figure 31. A visualisation of the design process to structure and summarise the steps that were taken to reach the initial design and final prototype.

3.2 Identifying themes

How can the design goal serve as guidance for the design process?

The design goal is:

1. To create a distracting and calming (AR) experience for children during venipuncture

2. by guiding attention to an engaging digital world, without hiding the physical procedure in a way

3. that improves the procedure experience for both the child and the nurse.

4. while being easy to implement in a clinical workflow.

In order to achieve all different aspects of the design goal, the design goal was dissected into four parts, see Figure 32. Each part led to a design question, which was summarised to a theme. The four themes are:

1. Distracting and Calming
2. Sense of Control
3. Procedure Experience
4. Implementation

Each theme helps to define key features: the building blocks for the final design. Key features are defined by synthesizing data from earlier chapters. The most relevant theme is Distracting and Calming, as it is directly tied to answering the research question. To ensure a comprehensive identification of key features within this theme, additional exploration was conducted using design methods. This process will be further elaborated in the next chapter.

Design goal	Design question	Theme
To create a distracting and calming (AR) experience for children during venipuncture	What types of visual, auditory, and interactive features are most effective in calming children and distracting them during venipuncture?	**Distracting and calming**
by guiding attention to an engaging digital world, without hiding the physical procedure	What features guide attention to an engaging digital world, without hiding the physical procedure?	**Sense of control**
in a way that improves the procedure experience for both the child and the nurse	What features help improve procedure experience?	**Procedure experience**
while being easy to implement in a clinical workflow.	What features contribute to an easy implementation in the clinical workflow?	**Implementation**

Figure 32. A schematic overview of how the design goal was dissected into four different parts, leading to four research questions and four different themes.

3.3 Design methods for Distracting and Calming

What types of visual, auditory, and interactive components are most effective in calming children and distracting them during venipuncture?

In order to answer the chapter question, three design methods were used: Co-creation, How-Tos and Design Benchmarking. All three methods will be further elaborated in this chapter. Together with data from the Research and Define phase, key features were identified to include in the final design. In *Chapter 3.4: Identifying Key Features*, they are summarized.

Method 1: Co-creation

Goal: Empathizing with the target group (children aged 6-12 years), exploring what makes them feel calm and gathering insights into their tacit knowledge through creative engagement.

Method

Co-creation, as a collaborative design method, engages users, designers, and stakeholders to develop user-centered solutions (Stappers et al., 2014). By fostering shared understanding, it ensures alignment with the users' needs and context. For this project, this method was particularly beneficial for children aged 6–12, who cannot always express their thoughts verbally but can express them creatively. Following a course on "Co-creation with Youth," a detailed co-creation plan was created to guide the session and manage expectations (Appendix H).
In this session, generative design research techniques were employed, allowing participants to create outputs during a "make and say" session. Four participants were asked open-ended questions like: "What makes you feel calm?" and "What do you do when you are scared?" They created collages using paper, pencils, magazines, pens, and stickers. The session was designed to be open and flexible, encouraging additional conversations about venipuncture, hobbies, and play. Clear guidelines were established, emphasizing respect and giving one other space to speak.

Recruitment and participant selection

Four Dutch boys, aged 7–8, were recruited via a personal network. All participants were classmates and belonged to the same friend group. Of the four, three had undergone venipuncture at least once.

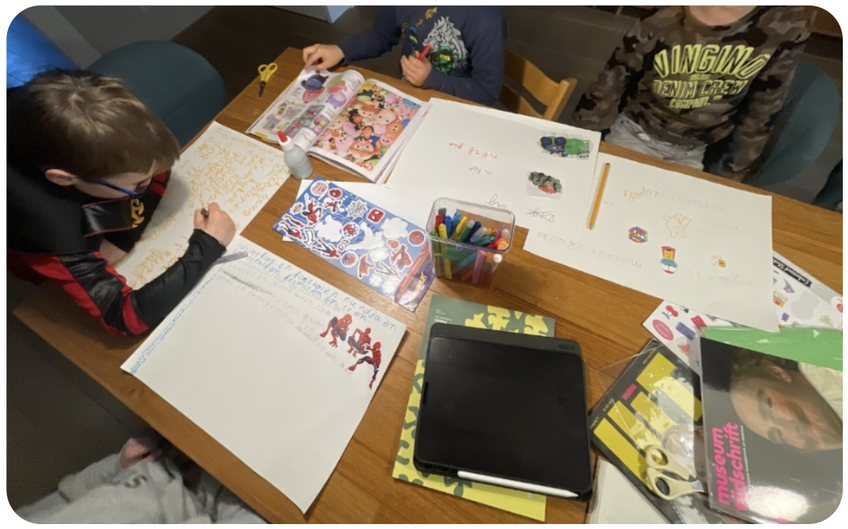


Figure 33. Participants during the co-creation session as they were working on their collages.

Data analysis

Audio recordings of the session were transcribed to highlight key comments. Collages and other creative outputs were also analyzed and are, together with transcript highlights, available in Appendix I. Furthermore, data was obtained from observing.

Observations

- Quiet focus: Initially, the children worked diligently and quietly, showing high levels of concentration.
- Social influence: Once one child wrote down a word, such as "football," others quickly followed, highlighting the influence of group behavior.
- Distractions: After approximately 30 minutes, the children's focus began to wander off. When one child became distracted the rest followed.

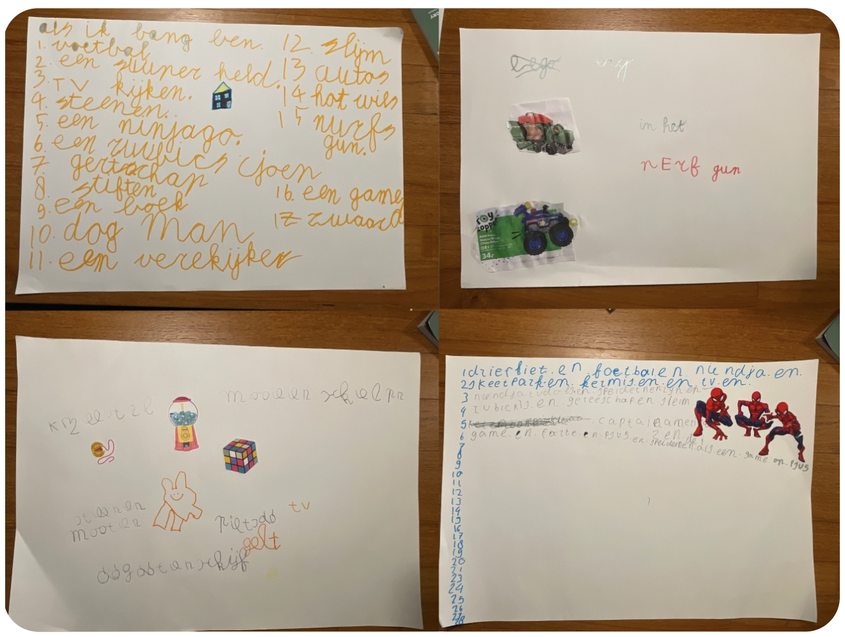


Figure 34. Collages created by participants, for a full version see Appendix I.

Findings

Children thought of personal and specific answers when asked about what calms them and what they do when they are scared. Their responses included hobbies and items such as football, Legos, crystals, nice shells, Rubik's cubes, chewing gum machines, pizza, watching TV, money, and agate disks. These answers revealed their personal interests, and were perhaps not always related topic of calming experiences.

When discussing calming moments, the following quotes stood out:

> *P2: "I am gonna draw a house! Because when I am scared I think about a house"*
> *Researcher: "Why?"*
> *P2: "Because ehh.. ehmm. ehh because I think houses are pretty."*

> *P4: I am never calm at home. I cannot become calm.*

Figure 36. iPad drawings created by participants.

When talking about venipuncture, the following quote was noted:

> *P4: "Puncture I find scary! Once there stepped a pony on my foot (almost broke my foot) and that was less scary. Because then I knew what they were gonna do: bandage on it and looking at my leg."*
>
> *P4: "The thing in the hospital (needle) looks so pointy and painful.."*
> *Researcher: "Did someone ever tell you it would hurt, or is that what you say to yourself?"*
> *P4: "I say that myself..."*

When answering the question "What do you like to do?" one participant answered:

> *P1: "Anything but girl stuff!"*

Conclusion
Although children showed their personal preferences and hobbies in response to the question, observations during the session revealed a consistent calming effect from creative and sensory activities, particularly drawing and making something. A notable example was their interaction with a ‘lightsaber-like’ brush on an iPad. Children became very quiet and concentrated while drawing. They created their own challenges, such as writing their name or coloring the entire screen. They found the glowing, dynamic appearance of the brush highly appealing, describing it as “cool” and expressing a desire to make it brighter. The activity was captivating because it offered a unique, sensory experience they had not seen before.

Reflection
The phrasing of the main question may have been too abstract for the children, leading to responses that weren’t directly tied to the intended topic. Many children wrote down simple or recently learned words, such as “tools” (gereedschap) and “binoculars” (verrekijker), potentially driven by their immediate recall rather than deeper reflection. The medium of writing (which they chose over the magazines and stickers) appeared to distract some participants, as they frequently asked how to spell words. This suggests that the act of writing may have drawn attention away from their ability to provide thoughtful answers. Also, four boys from the same friend group are not a representative user group and they might have also influenced each other in their answers.

Takeaways for key features

- Calming through creation: providing tasks that involve drawing or making something helps children feel calm and focused
- Sensory elements: the visual of a glowing element was very engaging and effective for calming and capturing attention
- Avoid stereotypes: be mindful of avoiding gendered or limiting design elements to ensure inclusivity

Method 2: How-Tos

Goal: To map out what possible interactions there are to distract and calm.

Method
The ‘How-To’ method is an individual brainstorming technique, dealing with the question of ‘how to do something’ and the action verb is key to forming this question. So, How-Tos are problem statements written in the form of questions that support brainstorming and idea generation (van Boeijen et al., 2014). In this project, there were two sessions.

During the ‘How to Distract’ brainstorm session, distraction methods were divided into two categories: active and passive. Each category was explored with various activities and elements. One identified risk of active distraction methods, such as gaming, is that they can disrupt the venipuncture procedure if the patient moves during the activity, see Figure 37. As a result, a follow-up brainstorm was conducted with a stronger focus on calming techniques. The advantage of calming techniques is their dual function: they not only distract but also reduce stress and anxiety. Consequently, a calming technique that incorporates distraction elements emerged as a promising solution, combining the benefits of both approaches. This insight led to the next brainstorming session: ‘How to Calm.’

Takeaways for key features

- A breathing exercise fits really well in the context of venipuncture procedures, as it helps to release muscle tension
- The distraction should be passive for most of the time, as that fits best in the context (no movement)
- The interaction should have calming audio, through music and/or sound effects.

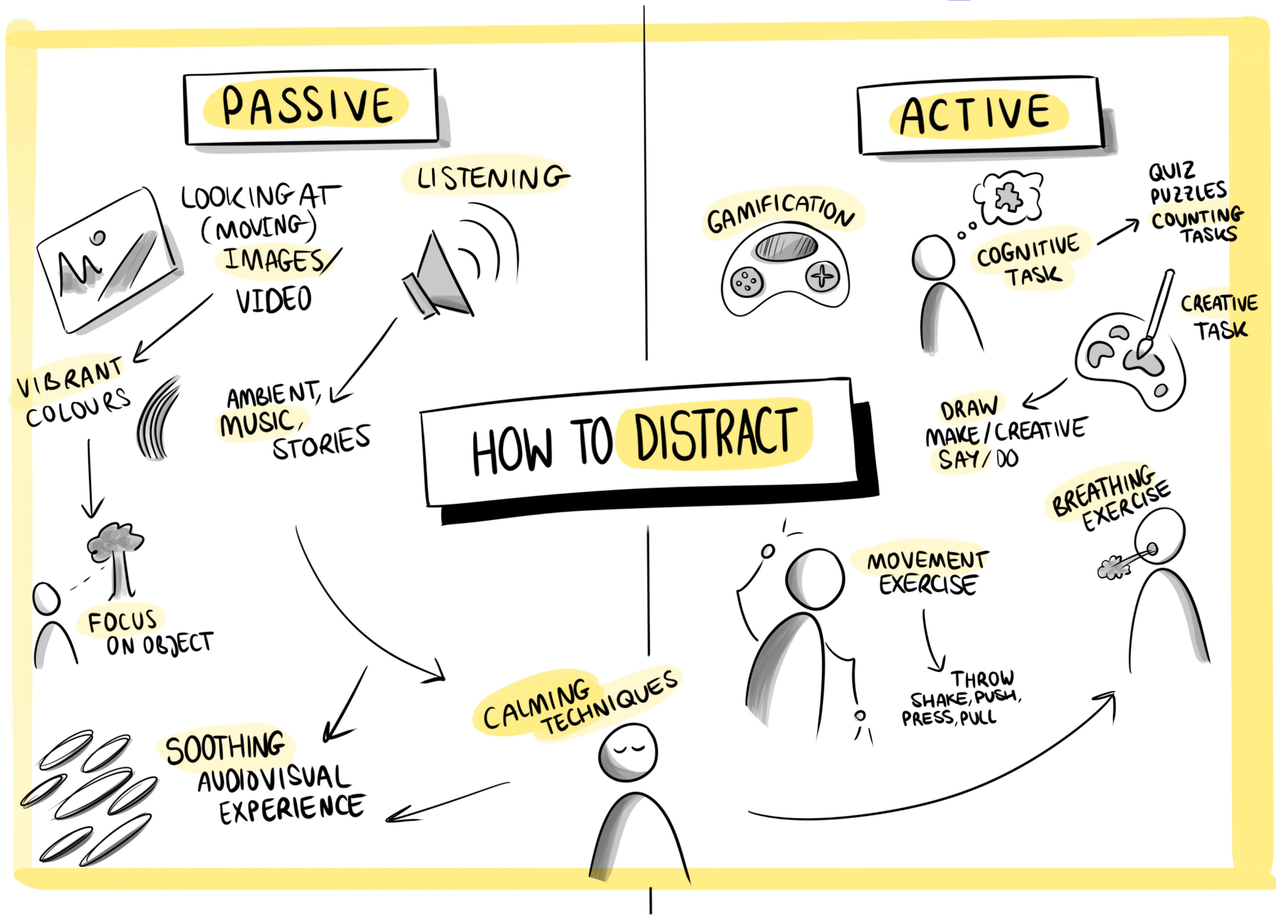


Figure 37. Drawings of the How-Tos sessions.

Method 3: Design Benchmarking VR Calming applications

Goal: To compare existing calming applications to identify effective audiovisual elements for calming AR experiences.

Method

Benchmarking is a systematic method used to evaluate and compare existing products, services, or processes to identify best practices and inform the development of new designs (Luchs et al., 2015). Design benchmarking involves systematically analyzing existing applications and experiences to identify effective design features that can be applied to new solutions. For this project, existing calming VR applications were evaluated to understand how they achieve calming and engaging user experiences. Three VR applications were selected and compared through evaluation criteria, whereafter conclusions were drawn and findings were listed. This method was particularly useful because it provided concrete design inspiration, helping identify which elements—such as visuals, sounds, and interactions—were most effective for creating a calming effect.

Selected VR Applications

Since there were no calming applications suitable for AR available in the Meta Store, VR calming applications were selected and analysed that were readily available for the Meta Quest 3. The selected VR applications were VRelax (VRelax BV, n.d.), Serenity (Serenity Developers 2022) and Nature Treks VR (Greener Games 2019), see Figure 38.

Evaluation Criteria

The following criteria were established to systematically evaluate the selected applications:

- Environmental Features: The type of 3D environment the experience took place in.
- Graphic style: The shapes, textures and colours of the objects in the experience.
- Movement and Pacing: The speed and flow of objects and animations.
- Auditory Design: The types of sounds used (e.g., nature sounds, ambient music) and their synchronization with visuals.
- Interactive Features: The presence of user-engagement elements (e.g., breathing exercises, object interaction).

Takeaways for key features

- Natural environments: The majority of the calming apps used nature environments as a contribution to relaxation.
- Auditory design: The combination of nature sounds and calming music was highly effective in maintaining user focus and reducing stress. Sounds of rustling leaves, flowing water, and birdsong added to the immersive experience.
- Interactive features: Interactions involving soft, glowing elements (e.g., touching glowing objects or following their movement) were described as engaging and comforting.
- Pacing and movement: Slow and predictable movements (e.g., floating objects or gently swaying trees) helped create a soothing experience, rather than rapid or unexpected movements. What worked best were slow-moving, magnificent scenes, creating a meditative atmosphere.

Discussion

The benchmarking of VR calming applications provided useful insights into effective audiovisual elements for relaxation, such as natural environments, slow movement, immersive sounds, and glowing interactive elements. However, the lack of child-specific design considerations in these applications means that their effectiveness may not fully translate to a younger audience. Children may require more dynamic, narrative-driven interactions to sustain engagement, particularly during a stressful medical procedure like venipuncture.

Evaluation criterium	VRelax	Serenity	Nature Treks VR
Environmental feature	Natural scenes: lake, forest, sky, stars Indoor scenes: Singing bowls temple	Natural: forest, grass, sky Abstract scenes: plain background with objects floating	Many types of customisable scenes, ranging from forests to underwater ocean experiences
Graphic style	Realistic, pastel colors and glowing	Realistic, pastel colors and glowing	Very realistic landscapes, with game-like interaction buttons
Movement and pacing	Slow, almost no movement except own head movement	Slow, almost no movement except own head movement	Slow pacing, gentle flow
Auditory design	Vibraphone like instruments, nature sounds	Vibraphone like instruments, nature sounds	Calming nature sounds and repetitive piano music.
Interactive features	Breathing exercise through musical input and head tracking, making music with singing bowls	Breathing exercise through musical input and head tracking, making music with singing bowls	Build a personal environment through e.g. planting flowers and animals

Figure 38. Brief benchmarking overview of different VR calming applications.

3.4 Identifying Key Features

What key features can be identified for the four different themes?

Figure 39. A visual overview of key features with corresponding numbers to the table.

Key features are core design attributes or functionalities that are essential to achieving the design goal, serving as building blocks for ideation. They were identified from data from the Discover chapter, Define chapter and from design methods in the Develop chapter. The features are categorized per theme. Figure 39 visualises key features alongside their corresponding number in the table (Figure 40) to make the feature more tangible.

Distracting and calming

What types of visual, auditory, and interactive features are most effective in calming children and distracting them during venipuncture?
Together with the three used methods for this chapter and data from the Discover and Define chapter, key features for distraction and calming were identified. They are listed in the following figure, with feature numbers 1-4.

Sense of control features

What features guide attention to an engaging digital world, without hiding the physical procedure?
As stated in *Chapter 1.2: Theoretical Perspective of Distraction:* "When attention is directed toward fear and pain, these sensations intensify". Therefore, it is important to move attention away from the procedure and the needle in particular. Thus, there should be objects moving away from the procedure and focussing on the engaging digital world. Doing so, it is important to respect the different archetype viewing directions that were stated in Chapter *2.2: Defining control per archetype.* This means that there is not one predefined perspective to look at in the AR experience, but the viewing direction is flexible. Distraction elements should be visible for all archetypes, within all directions.

Meanwhile, it should always be possible to look at the physical original procedure so that children do not feel the need to peek underneath the headset and see what is physically happening.
The findings for the key features were summarised in the following figure.

Procedure experience features

What elements help improve the procedure experience?
To enhance the overall procedure experience during venipuncture for both the child and the nurse, several key features were identified to address their distinct, and at times, conflicting needs. While the child seeks positivity, understanding, and a sense of control, the nurse is primarily concerned with ensuring procedural efficiency, patient cooperation (by sitting still and relaxing muscles) and maintaining a calm environment. The challenge lies in balancing these differing concerns to create a positive experience for both stakeholders.

Implementation features

What features contribute to an easy implementation in the clinical workflow?
To ensure the AR experience can seamlessly integrate into the clinical workflow of nurses, it is crucial that its implementation does not add unnecessary complexity or extend the duration of the procedure. Moreover, as stated in *Chapter 2.3: Interaction Boundaries,* the exact duration of the venipuncture procedure varies strongly per patient. Therefore, the AR experience should not be dependent on time constraints.

	#	Key feature	Explanation	Derived from
Distracting and calming	1	😮‍💨 **Breathing exercise**	Achieves effective active distraction as it is a cognitive task, with a bonus of mental and physical (muscle) relaxation.	Existing interventions (1.4) Stakeholder interviews (1.5), How-Tos and Design Benchmarking (3.2)
	2	🎶 **Soothing music and nature sounds**	Contribute to relaxation through slow, major key (soothing) melodies and also serving as auditory distraction.	How-Tos and Design Benchmarking (3.2)
	3	🌄 **Captivating and visually pleasing landscape**	Contributes to relaxation, with various elements that not only arouse curiosity, but also capture attention and keep it. It is important that the surroundings remain interesting overtime, therefore elements should be visually pleasing.	Theoretical perspective of distraction (1.2), How-Tos and Design Benchmarking (3.2)
	4	🌟 **Glowing objects**	Have proven to be mesmerizing through its enchanting effect, offering a lot of potential for capturing attention.	Co-creation and Benchmarking (3.2)
Sense of control	5	👀 **Object moving away from puncture procedure**	Invites the patient to look at the digital world by guiding the viewing direction away from the procedure with an object that they can follow along.	Stakeholder interviews (1.5)
	6	🔀 **Placing objects in different viewing directions**	Enables flexibility for viewing perspectives, respecting the different archetypes using the headset. There should not be a predefined viewing direction: distraction elements should be visible for all archetypes.	Defining control per archetype (2.2)
	7	💉 **Show original procedure with pass-through**	Allows the patient to freely shift their gaze between the real-world procedure (via AR pass-through) and the engaging digital environment. This freedom of choice in looking contributes to a sense of control.	Sense of being in control (1.6)
Procedure experience	8	😊 **Positive language and tone**	Sets a rewarding and supportive mood during the procedure by using encouraging phrases and framing instructions as challenges or fun tasks, making the patient feel empowered, reinforced and more in control.	Stakeholders and concerns (1.5), Sense of being in control (1.6)
	9	🏆 **Sitting still reward**	Helps the nurse performing procedure steps and turns a serious instruction into a fun challenge for the patient.	Stakeholders and concerns (1.5)
	10	🐒 **Main character as a buddy**	Serves as a comforting and empowering buddy for the child throughout the procedure, making them feel empowered and not like it is “them alone against the adults”.	Stakeholders and concerns (1.5)
Implementation	11	🫳 **Intuitive procedure related controls**	Makes it easy to use at first sight, without requiring any additional explanation from the nurse, by using interactive controls that are closely aligned to procedural steps.	Interaction Boundaries (2.3)
	12	🔄 **Looping**	Makes it flexible for varying procedure durations without interruptions or manual resets.	Interaction Boundaries (2.3)

Figure 40. Overview of key features per theme, what they provide and where they have been derived from.

3.5 Ideation and concept direction

What concept themes are explored that lead to the final concept?

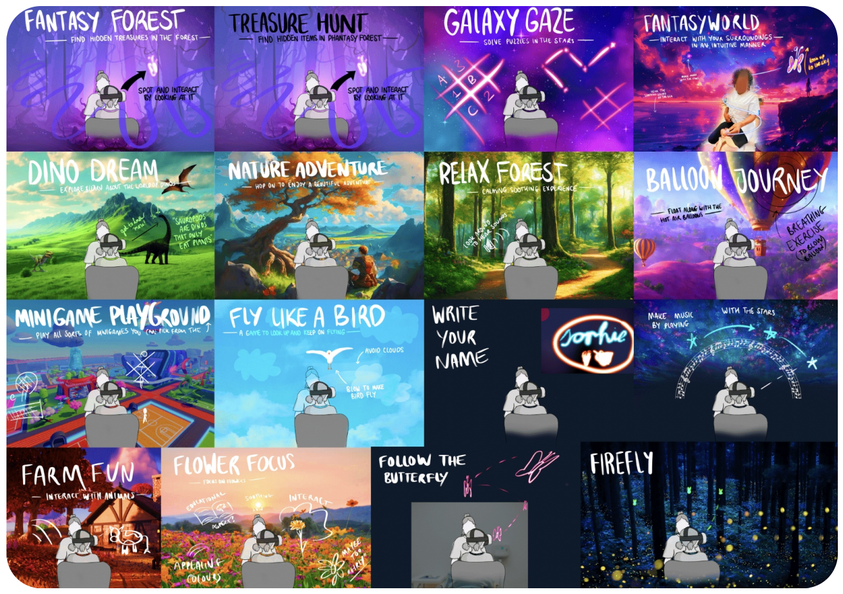


Figure 41. Idea sketching for the concept.

Figure 42. Balloon Journey Concept.

With key features derived from the design goal themes, the ideation phase could start. Using the features for 'Distracting and Calming' as foundational building blocks, multiple concept themes were explored, drawing inspiration from *Chapter 1.8: Target Group*. Furthermore, brainstorming methods such as PLEX and Collage making were used as inspiration tools, see Appendix J. As a result of ideation, 16 themes were sketched out that were narrowed down to 3 concept directions. Each concept direction is briefly explained, showing its challenges and limitations, a reference to Distracting and Calming key features and an argumentation with Game Design Values from *Chapter 1.8: Target Group*. A full explanation on the concepts can be found in Appendix K.

The concepts were evaluated with the list of wishes from *Chapter 2.6: List of Requirements and Wishes*. Using the Weighted Objectives method (Roozenburg & Eekels, 1998) in Appendix L, alongside a feedback session with Sophia Children's Hospital. Based on this evaluation, the Firefly Forest concept was selected. However, feedback from the client indicated that the theme's dark color scheme might not be ideal for young children and suggested a brighter, more colorful visual style.

1. Balloon Journey

Balloon Journey immerses children in a playful and soothing environment where they gently blow to inflate colorful balloons, watching them float into a dreamy sky filled with clouds and interactive fantasy elements. This encourages slow, controlled breathing while maintaining an engaging and lighthearted experience. The interaction fosters a sense of fun and playfulness, as children enjoy the simple cause-and-effect of their breath shaping the world around them.

Challenges and Limitations

The act of blowing could introduce unintended body movement, which may interfere with the need for stillness during venipuncture. Additionally, the experience relies on a minimal narrative, which may not hold engagement for older children over time.

Key features

😮‍💨 **Breathing exercise** - Blowing the balloons simulates deep breathing and aids muscle relaxation.

🎶 **Calming music and nature sounds** - Cheerful background music blends with gentle wind sounds and birds that fly by.

🌄 **Beautiful landscape** - A sky full of fluffy clouds and vibrant balloons.

🌟 **Glowing objects** - Balloons start to glow when inflated, offering visual feedback and rewards.

Figure 43. Music in the Stars concept.

2. Music in the Stars

Music in the Stars transforms the AR experience into an interactive encounter, where children create their own melodies by gazing at glowing stars in the sky. Each star they focus on produces a soft note, allowing them to compose a personalized, soothing harmony. Considering innovation as a key game design value, this concept introduces a novel way of making music, allowing even those without prior musical experience to engage in composition. The music is programmed to always be in harmony, ensuring a pleasant and calming auditory experience.

Challenges and Limitations

The interaction requires active participation, which may not be suitable for all children, especially those who prefer a more passive distraction. Additionally, younger children might need guidance to fully understand the gaze-based mechanics.

Key features

😮‍💨 **Breathing exercise** - A pulsating star rhythmically guides the child's breath.

🎶 **Calming music and nature sounds** - Self-composed melodies that are soothing and calming with a wind ambient sound.

🌄 **Beautiful landscape** - A peaceful night sky with glowing constellations.

🌟 **Glowing objects** - Stars pulse and emit light when interacted with, creating a calming effect.

Figure 44. FireFly concept.

3. FireFly Forest

Firefly Forest transports children to a glowing, enchanted forest where fireflies respond to their stillness and breathing in a magical, rewarding manner. As they sit calmly, fireflies gather and create mesmerizing patterns, reinforcing relaxation and focus shifting. This helps to calm and distract, as it requires minimal effort from the child while offering a sense of wonder and engagement.

Challenges and Limitations

The darker theme of the environment may not appeal to all children, as night-like settings can sometimes be associated with fear. Additionally, some children may prefer a more interactive challenge rather than a primarily passive experience. Ensuring a seamless transition between AR and the physical environment requires careful calibration to maintain immersion.

Key features

😮‍💨 **Breathing exercise** - Fireflies pulse in sync with the child's breath, guiding a relaxation rhythm.

🎶 **Calming music and nature sounds** - A blend of soft forest sounds and soothing background music.

🌄 **Beautiful landscape** - A glowing, interactive forest with dynamic natural elements.

🌟 **Glowing objects** - Fireflies illuminate the space, rewarding calm behavior with visual engagement.

3.6 Prototype development

How was the AR experience developed in Unreal?

The development of the AR experience in Unreal Engine 5.3 was done without prior experience in the field. To provide enough space for the learning process, the process development was structured into three different sprints, each with a specific goal and key takeaways. The first sprint focused on familiarizing with the Unreal Engine 5.3 software and Meta Quest 3 hardware by building a Minimum Viable Product (MVP) and testing it with the target group. This provided insights in how the target group responds to a self-developed AR experience in an early stage of the design process. The second sprint involved developing the Firefly theme integrating core design elements and iterative usability testing amongst peers in the XR Zone to identify early-stage improvements. The final sprint aimed to refine and develop a high-fidelity prototype, polished for testing with the target group. For a detailed logbook documenting the development process, see Appendix G.

Figure 45. MVP Testing with the target group in Sprint 1.

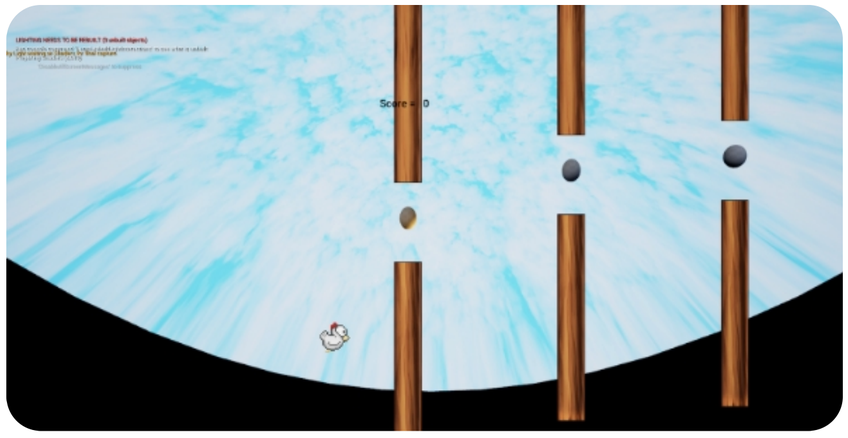


Figure 46. Interface of MVP with black areas being pass-through.

Sprint 1: MVP Building and testing

Goal: Familiarization with technology through an open exploration of the capabilities of the Unreal Engine software and Meta Quest 3 hardware. Moreover, it provided insights on how the target group responds to Virtual Reality.

Explanation

Before the ideation phase, a Minimum Viable Product (MVP) was developed and tested with the target group. A Minimum Viable Product (MVP) is a development technique used to create a simplified version of a product with just enough features to gather feedback and validate core concepts (Ries, 2011). It enables designers and developers to test their assumptions, identify potential challenges, and iterate on the design with minimal effort and resources. The MVP consisted of an interactive game in the clouds, directly inspired from the Interaction Vision. It was built with a pass-through environment, where users were tasked with helping a main character ‘Kippie’ fly and avoid obstacles. If Kippie fell, the user was challenged to complete a breathing exercise to help it fly again.

Takeaways

Avoid game-like interactions: Game-based interactions overly excited children, leading to excessive movement, which could interfere with the goal of keeping them still during the procedure.
Positive response to characters: Children reacted enthusiastically to the presence of a main character, highlighting its potential for engagement and emotional connection.
Bright engaging colors: Children found the vibrant visuals appealing, enhancing their overall experience.

Sprint 2: Functional Prototype

Goal: Program, build, and test core interactive elements.

Explanation
After selecting the Firefly theme, a functional prototype was developed to test key design elements, such as fireflies spawning based on head-tracking movement. A blueprint script was implemented (see Figure 47), enabling fireflies to appear when minimal head movement was detected and disappear upon excessive movement. This mechanism was tested with peers and proved to be effective in encouraging stillness while maintaining engagement.
To create a calming environment, a natural landscape was designed. However, many of the 3D objects were too high-poly, leading to performance issues on the Meta Quest 3 headset, requiring significant reductions in object density. This provided valuable insights for the final prototype. Additionally, the pass-through feature, which allowed users to see the real-world procedure, was implemented. Due to technical software limitations, a smooth gradient-like transition between the physical and digital worlds was not feasible, resulting in a pass-through feature with a capsule-shaped overlay.

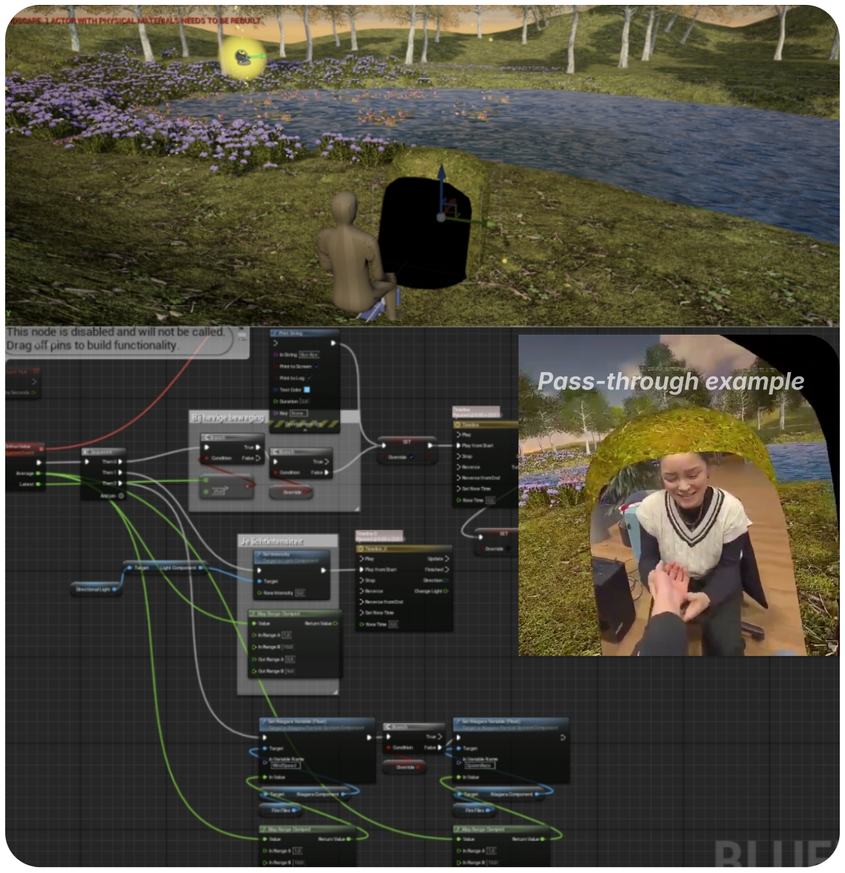


Figure 47. Screenshots of the functional prototype, showing the pass through. Below, there is a screenshot of the coding blueprints for the firefly interaction, based on head-tracking movement.

Takeaways
Proof of concept: (Dis)appearing fireflies based on head movement tracking
Performance optimization: High-poly objects significantly affected performance and required simplification for the next prototype.
Pass-through limitation: It was not possible to achieve a smooth transition between the physical and digital environment, this should be acknowledged in general prototype limitations.

Sprint 3: Final Prototype

Goal: Developing the final prototype and polish for testing.

Explanation
The final sprint focused on creating a prototype that was visually engaging for the target group and optimized for testing. To reduce the likelihood of bugs during testing, the Wizard of Oz technique (van Boeijen et al., 2014) was employed, meaning user interactions were simulated manually instead of being fully functional. Unlike the functional prototype from Sprint 2, user inputs—such as head movement—were not automatically detected by the system. Instead, interactions were manually triggered using keyboard shortcuts to ensure smooth operation during testing. This design was also tested with peers.

Figure 48. Imported objects for starting to build the final prototype.

Figure 49. Testing with peers.

Developing the main character

A main character plays a crucial role in making the AR experience more engaging and emotionally supportive for children undergoing venipuncture. This was earlier explained in *Key Feature 10: Main character as buddy* and during the early prototype testing in *Sprint 1*, it was again confirmed how much children enjoyed having a main character as part of the experience. The main character serves multiple functions: providing the child with a sense of companionship, guiding them through the breathing exercise, reinforcing positive behavior, and enhancing overall engagement. A design exploration was done to the develop this main character, resulting in: Lumi.

Lumi

The development of Lumi, the firefly companion, began with sketching, exploring various shapes, proportions, and expressions to ensure the character felt friendly and approachable, see Figure 52. After finalizing a concept, the design was translated into 3D using Blender (Figure 51), where different materials and lighting effects were applied to achieve the desired soft glow. The low-poly style was deliberately chosen to align with the technical constraints of the AR environment while maintaining an engaging child-friendly aesthetic.

Appropriateness

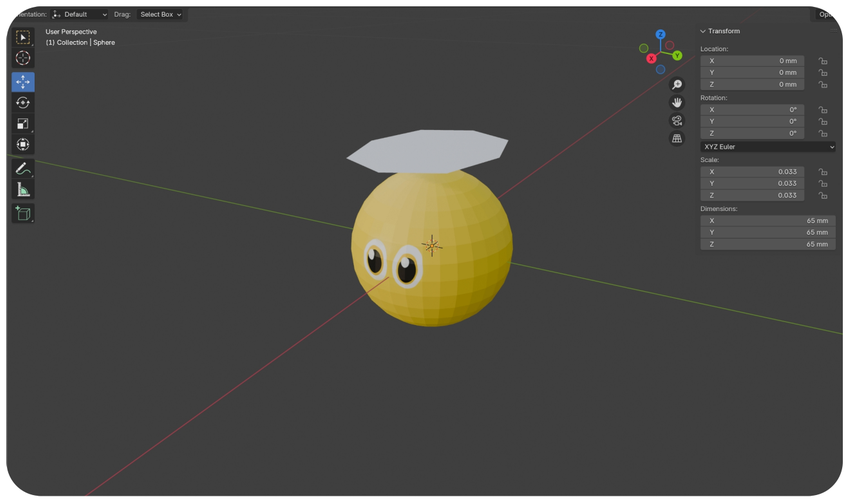
Lumi's design was carefully tailored to be universally appealing to children between 6 and 12 years old, ensuring it resonates across different developmental stages and preferences. For younger children, its rounded shape, large eyes, and soft glow make it appear friendly and non-threatening. Older children benefit from a simple design that avoids an overly cartoonish style, keeping it engaging without feeling overly juvenile. Lumi is also gender-neutral, ensuring broad appeal without relying on stereotypical design elements.

Technical feasibility

To ensure smooth performance in AR, Lumi was developed using a low-poly modeling approach in Blender. An earlier approach was not feasible, as it had too many details, see Figure 50. Low-poly modelling of Lumi allowed for an optimized real-time rendering experience while maintaining a recognizable and appealing aesthetic.

Lumi is more than just a visual element—it actively contributes to the AR experience by synchronizing with breathing exercises and providing positive reinforcement when the child remains still. This dynamic interaction ensures that Lumi is both emotionally supportive and functionally integrated into the venipuncture procedure, helping children feel at ease throughout the process.

Figure 50. Developing a more cartoon character, but that was not enough low-poly and contained a too literal style.



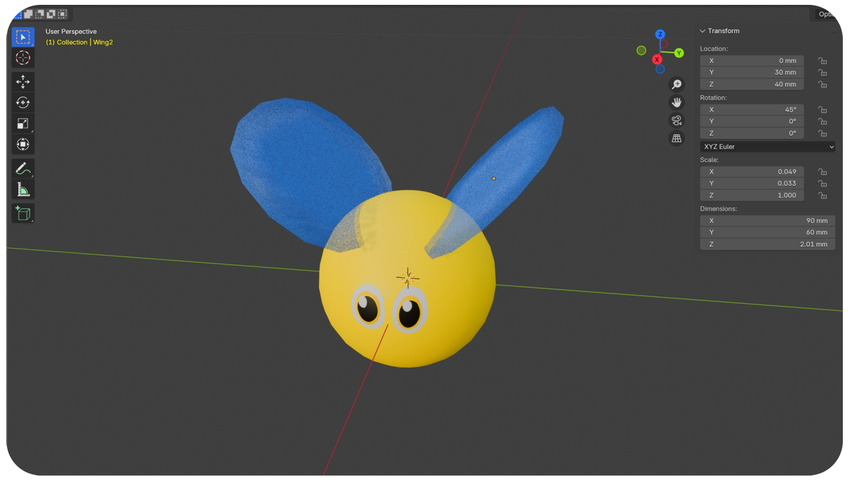


Figure 51. Developing the main character, Lumi, in Blender.

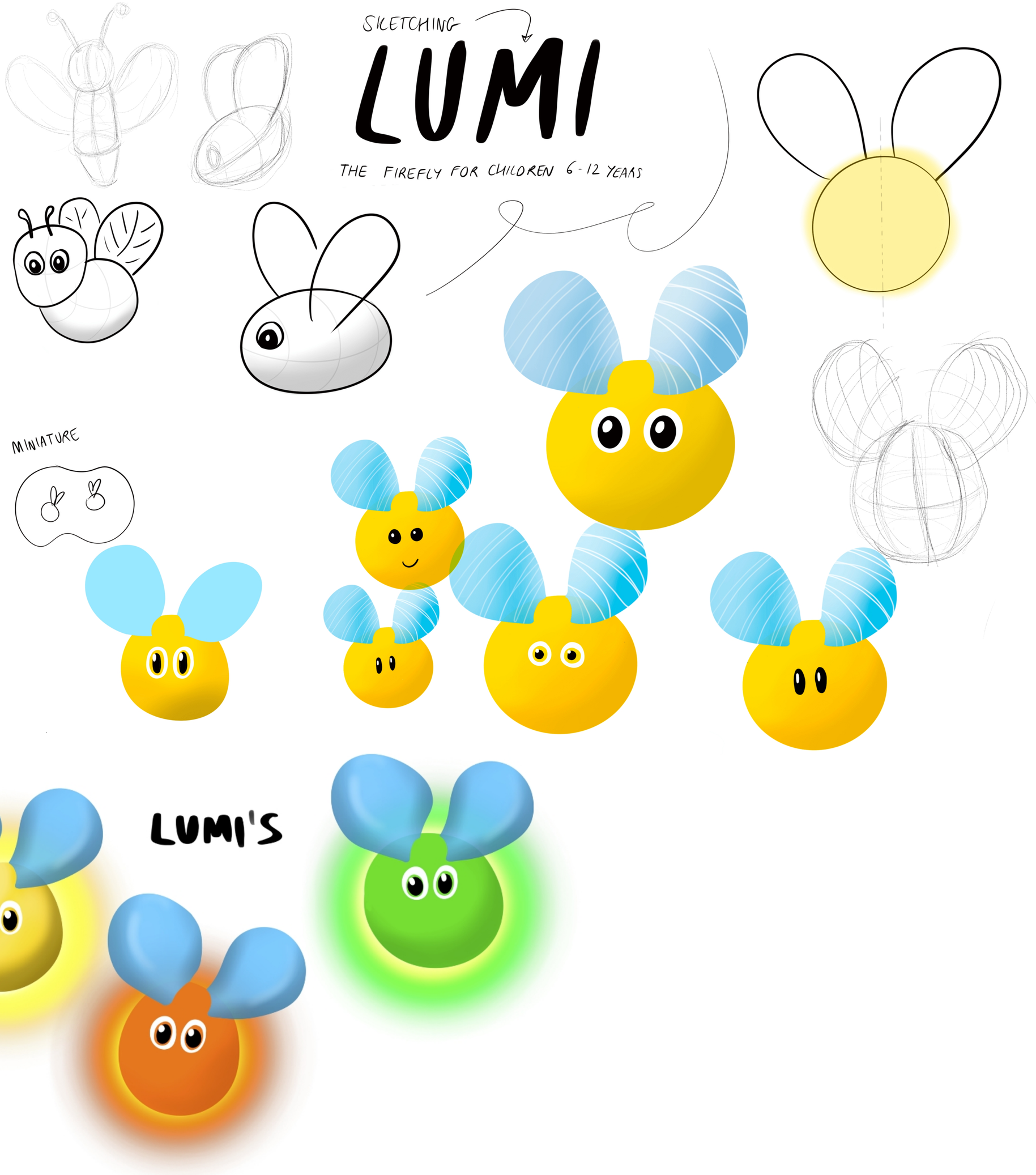


Figure 52. Sketching process for the final main character.

3.7 Pre- and post-procedure experience

How can the pre- and post-procedure experience enhance the AR interaction?

As mentioned in *Chapter 2.3: Defining Interaction Boundaries*, the **Waiting Room (pre-procedure)** and **Physical Souvenir (post-procedure)** experiences have the potential to enhance the overall effectiveness of the AR experience. Therefore, following the concept of Firefly Forest, an exploration into these additional experiences was conducted and evaluated with the client. These concepts are intended as conversation starters for future design projects, as they were not tested within this study.

Figure 53. The waiting room in the Sophia with a suggestion for a concept, showing its possible location.

Waiting room experience (pre-procedure)

Goal: Providing distraction during the waiting period, reducing awareness of waiting room sounds and tension buildup, introducing the FireFly theme to increase engagement when transitioning into the AR experience during the procedure, whilst ensuring that the experience is interruptible at any moment, allowing flexibility for unpredictable waiting times. The suggested position of this experience in the waiting room is sketched in Figure 53.

Method

To explore potential solutions for the Waiting Room Experience (pre-procedure), two How-To questions guided the ideation process. These questions are stated:

1. How to distract children in the waiting room?
2. How to introduce the FireFly theme before the procedure begins?

From answers to these How-To explorations, a Morphological Chart (Roozenburg & Eekels, 1998) method was used to generate and structure ideas, see Figure 54. 26 ideas were generated, of which three were chosen using the *2.6: List of Requirements*. These three ideas, as shown in Figure 55, are discussed with the client in the following section: *Conclusion through client evaluation*, drawing a conclusion for further design recommendations.

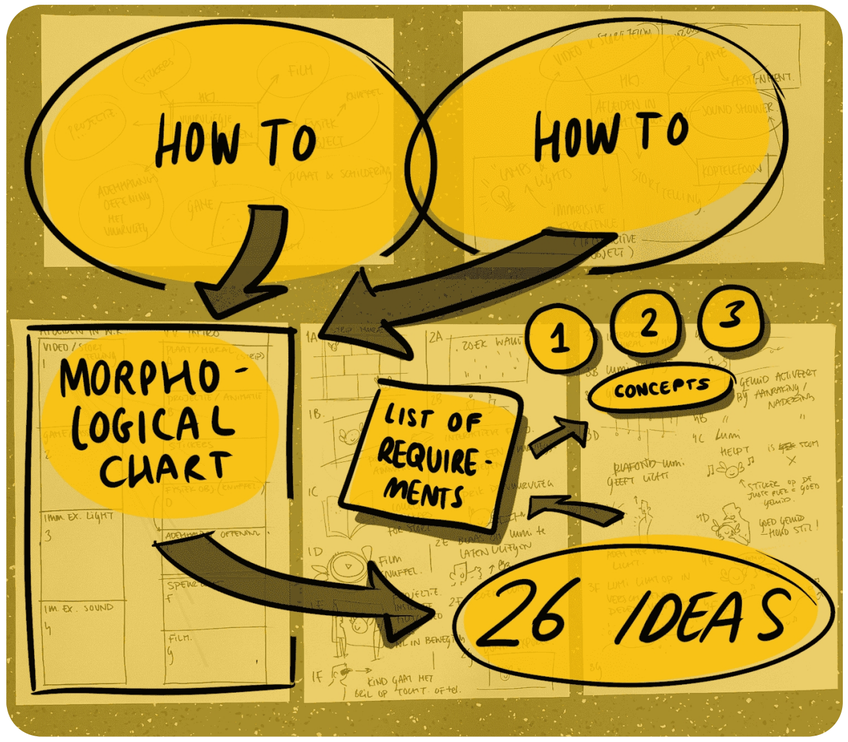


Figure 54. How-Tos and Morphological Chart Design explorations, for a full version, see Appendix N.

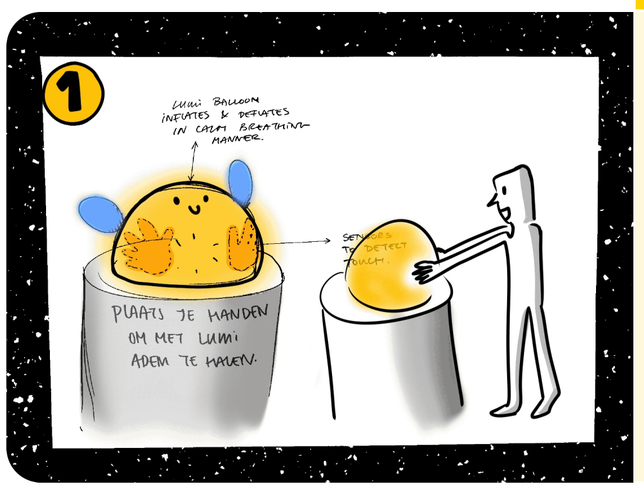
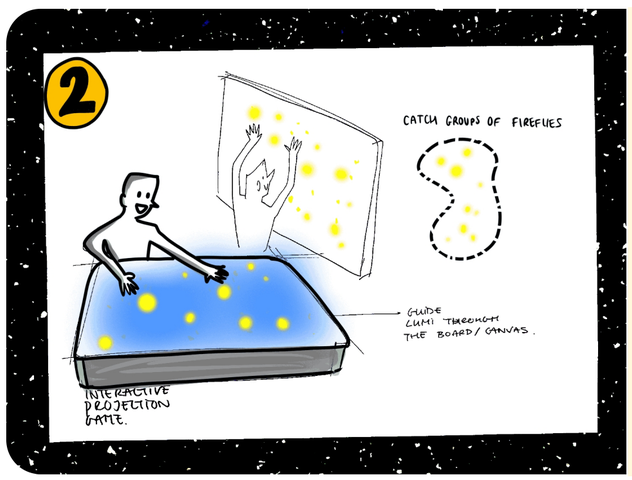
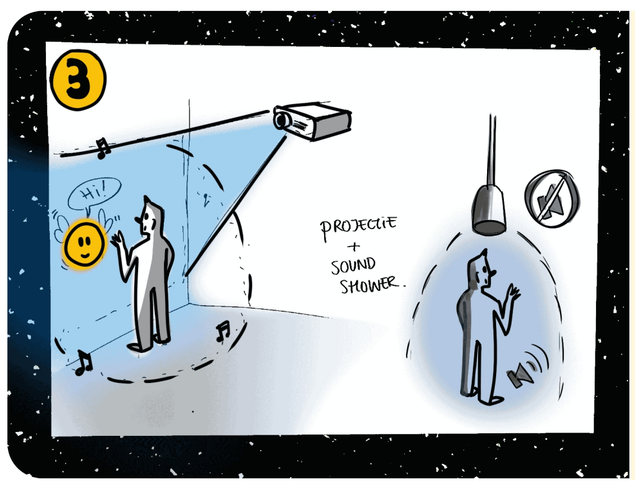
	Concept	Key features	Technology
	**1. Breathing balloon** A visually appealing breathing exercise where children follow the FireFly's movements (inflating and glowing brighter to inhale, shrinking and dimming to exhale) to regulate their breathing, helping them relax before the procedure.	Active calming distraction, eye-catching/attention grabbing **physical object** with an interactive **guided breathing exercise** using **visual and touch-sensitive cues**.	Balloon that inflates and deflates rhythmically using an internal air pump, motion sensors detect hand movements, internal LED system creating a soft pulsing glow that synchronizes with the inhale-exhale cycle.
	**2. Interactive game** A touch-responsive game where children collect fireflies by interacting with a screen or projection, making waiting time playful and engaging.	A **task** serving as distraction with a **game element,** could also be a **puzzle.**	Large screen using Capacitive Touch Technology, or Infrared/ Optical Touch if implemented as a projection-based system. A custom interactive game should be developed for this concept.
	**3. Projection sound shower** A storytelling experience where children listen to and watch the FireFly Forest's story, immersing them in the theme and easing their minds before the procedure.	A localised immersive **audiovisual storytelling experience** through a **video**.	A "sound shower" system is directional audio, meaning it is only audible when the listener is positioned directly in front of it. Additionally, a projector (beamer) will be used to display visuals, and a custom video will be produced to complement the experience.

Figure 55. Three concept directions for the Waiting Room Experience (pre-procedure) with their key features and technological features explained.

Physical souvenir (post-procedure)

Goal: Serve as a reinforcing reward, leaving the child with a positive memory of the procedure. Current physical souvenirs are shown in Figure 57.

Method
How can a souvenir reinforce a positive experience after venipuncture? To explore this, an interview was held with a mental healthcare psychologist.

Positive reinforcement
Positive reinforcement is a psychological principle that strengthens a behavior by providing a rewarding experience. In the context of venipuncture, a well-designed souvenir can:

1. Reframe the experience by shifting focus from discomfort to achievement.
2. Provide a sense of accomplishment, making children feel proud of their bravery.
3. Encourage future resilience, making the next medical procedure feel less intimidating.

By applying the How-To method, different approaches to positive reinforcement were generated, see Figure 56. This exploration led to three concept directions that are shown in Figure 58.

Figure 56. 'How-To Reinforce a Positive Experience' brainstorm.

Figure 57. Physical souvenirs that children can choose from in the Sophia hospital.

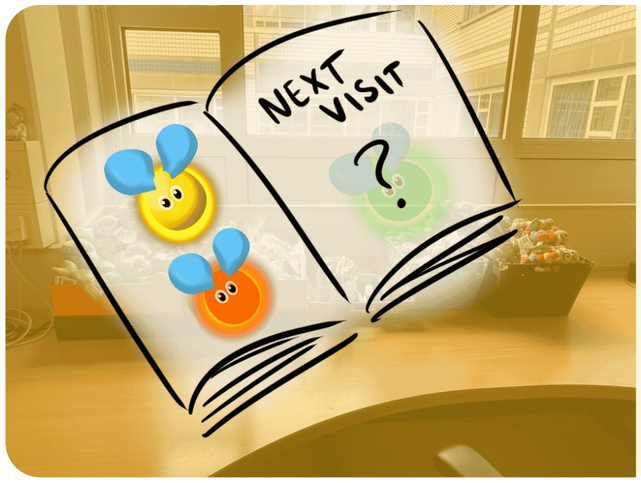
	Concept	Key features
	**1. Firefly toy** A physical souvenir of the procedure, made with recycled (hospital) materials. This is a friendly reminder for the child to hold on to, and has a light function to play along with.	Recycled hospital materials, light/ glow in the dark material
	**2. Booklet** A physical booklet that challenges to collect more stickers overtime to complete a story of the FireFly.	A storytelling booklet/passport that remains interesting overtime.
	**3. Certificate** A storytelling experience where children listen to and watch the FireFly Forest's story, immersing them in the theme and easing their minds before the procedure.	Piece of paper, include Lumi the FireFly. Interesting for single-time users.

Figure 58. Three concept directions for the physical souvenir (post-procedure) with their key features and technological features explained.

Evaluation with client

Goal: Draw a conclusion of the pre- and post-procedure explorations, therefore an evaluation session was held with the client, the Erasmus MC Sophia.

Method
The session was conducted as a semi-structured concept evaluation and ideation session, combining elements of structured feedback and collaborative exploration. The goal was to evaluate and refine three concept ideas for both the waiting room experience (pre-procedure) and the physical souvenir (post-procedure) while allowing space for creative adaptations. The discussion followed a semi-structured format, where predefined interview questions guided the conversation to ensure key aspects of the concepts were addressed, particularly in terms of feasibility, desirability, and effectiveness. The session remained open-ended, encouraging the client to reflect on the proposed ideas and suggest modifications or alternative directions.

Next to evaluation, the session also incorporated collaborative ideation, inviting the client to actively contribute to the refinement of the concepts. Each idea was presented both visually and verbally, followed by an iterative feedback loop, where insights gained from one concept could influence another. This flexible, participatory approach ensured that the final designs not only align with the practical constraints and needs of the hospital but also retain room for creative innovation and user-centered improvements.

During the evaluation session, the client emphasized that any proposed intervention should be feasible and cost-effective. Additionally, it should be standalone, meaning that no external devices such as phones or tablets should be required for interaction.

Figure 59. Evaluation session with the client, discussing the different concept ideas.

Waiting room experience (pre-procedure)
The client suggested to combine the Projection & Sound Shower concept (3) with a physical object like in the Firefly Balloon (1), see Figure 60. Rather than relying solely on projections, a physical element, such as a lamp shaped like the Firefly character Lumi, could serve as a tangible and engaging feature. However, to ensure durability, the physical object should be placed out of children's reach.

From a technological perspective, the client expressed a preference for a screen over a projection, as screens are more visually prominent and eliminate the issue of people walking in front of the display. Additionally, screens with some depth, slightly protruding from the wall, were seen as more engaging. However, considering cost constraints, a projection would be the more feasible option. The placement of the installation was also discussed, with a wall-mounted design being the preferred choice. Mounting the installation on the wall was seen as the most natural interaction, drawing more attention from children sitting in the waiting area than a table-based alternative.

Beyond serving as a distraction, the experience could also function as a preparatory step for venipuncture. Through a playful and engaging approach, children could practice holding their arm still as part of a game-like interaction. Introducing the Firefly character Lumi in this phase would help create familiarity, with the character offering a reassuring message such as:

"Hi! I'll also be there with you during the procedure."

This early introduction reinforces Lumi's presence during the actual venipuncture, helping to establish a sense of continuity and support.

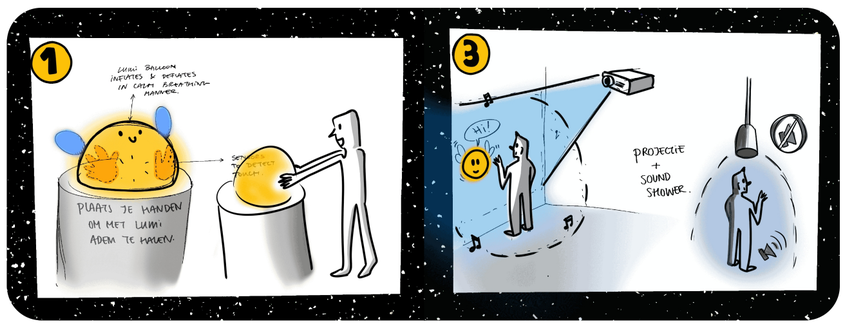


Figure 60. Concept 1 and 3 that are recommended to be combined.

Post-Procedure Experience (Physical Souvenir)
For the post-procedure experience, the client emphasized the importance of creating something that remains engaging over time. A simple one-time reward would not be enough, as children should feel encouraged to interact with it across multiple visits. Also, manufacturing little toys would not be cost-efficient nor sustainable.

To address this, a collectible sticker system was proposed, similar to a vaccination passport. Each time a child undergoes a procedure, they would receive a sticker, turning the experience into a form of progression and achievement. To ensure that the experience remains relevant for different age groups, the back of the passport could contain additional content tailored for older children. This could include short stories, fun facts, or engaging activities related to the Firefly theme, ensuring that the booklet remains a meaningful and interactive souvenir.

Key takeaways from client evaluation

- Feasibility & Cost Considerations: Any intervention should be cost-effective and easy to manufacture while ensuring durability in a hospital setting. Screens are preferred over projections due to their stronger visual presence and engagement potential. However, projections remain a more budget-friendly alternative.
- Standalone Interaction: The solution should be fully self-contained, requiring no external devices such as tablets or phones for interaction.
- Durability & Safety: Any physical objects in the waiting room should be placed out of children's reach to prevent damage and ensure longevity.
- Post-Procedure Longevity: A sticker collection system offers a sense of progression and storytelling, making the souvenir meaningful beyond a single visit. Alternatives, such as a stamp-based system or another collectible element, could also be explored to maintain engagement over multiple procedures.

Conclusion
The evaluation session provided critical insights into refining the pre- and post-procedure experience. The insights will be translated into final concept directions in the next chapter.

4

Deliver

With the insights from research, co-creation, and iterative design, the final AR experience, FireFly Forest, was developed to provide an engaging distraction for children undergoing venipuncture. This phase focuses on presenting the final design, evaluating its effectiveness through prototype testing, and exploring implementation possibilities within a clinical context.

To assess how well the design aligned with the stated design goal, an AR prototype was built in Unreal Engine and tested in a simulated venipuncture setting with children. Additionally, pre- and post-procedure experiences were explored to enhance familiarity before the procedure and reinforce positive associations afterward.

This section presents the finalized FireFly Forest design, the results of user testing, and considerations for further development and implementation in a medical setting.

4.1 Final design

Presenting the final AR design and concept directions for the pre- and post-procedure experience

Final design composition
The final design is composed of three interconnected parts, as illustrated in Figure 61:

- Pre-Procedure - Waiting Room Experience: Lumi's Portal
- In-Procedure - AR Experience: FireFly Forest
- Post-Procedure- Physical Souvenir: Lumi's Adventure

The core component of the design is the AR experience, which is introduced first as it plays the most prominent role during the venipuncture procedure. Following this, the concept directions for the pre- and post-procedure experiences are presented. While these concepts have not been tested with the target group, they serve as valuable conversation starters for future iterations and refinement.

To provide a holistic view of the patient journey and scenario, a storyboard is included at the end of this section, illustrating the three experiences and their interactive elements. This final representation ties the concepts together, emphasizing their relation to each other and desired effects.

FireFly Forest Theme
The FireFly Forest theme (Figure 62) has been developed as an interactive, immersive and calming experience. The **forest setting** contributes to a sense of calming through nature sounds and soothing visuals. The natural environment serves as a comforting backdrop, subtly encouraging relaxation. This is explained into more depth in the AR experience section.

The firefly, **Lumi**, was selected as the central element because it is both a fantasy-like character and a real animal, making the theme layered and adaptable for different age groups. For younger children, the glowing firefly feels magical and playful, adding an element of wonder to the experience. For older children, it offers an opportunity to learn about the real-world phenomenon of **bioluminescence** (etymology of Lumi's name) making the interaction both engaging and educational.

Additionally, the firefly's glow plays a crucial role in both calming and distracting the child. The soft, warm light provides a soothing visual experience, while the glowing effect captures the child's attention in both the waiting room and during the procedure.

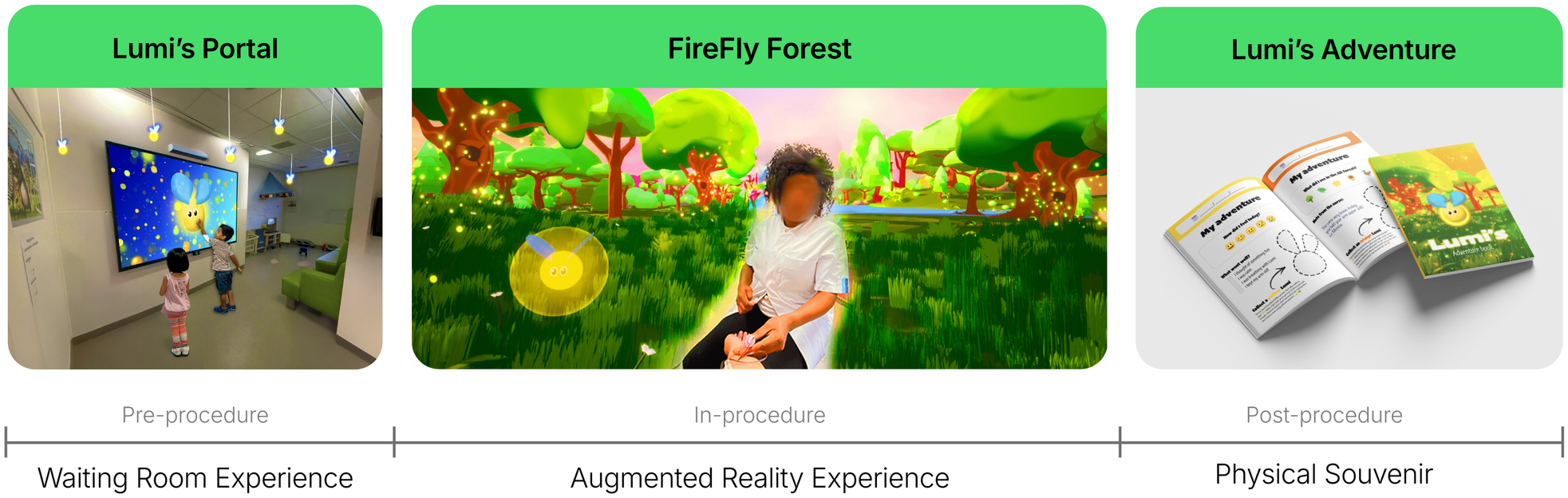


Figure 61. The three different designed experiences visualised in a timeline.

Figure 62. Lumi the firefly in his forest.

AR Experience: The FireFly Forest

Figure 63. The final AR design visualisation with a pass-through to reality of the nurse who is performing the puncture, and Lumi the firefly on the left, guiding the breathing exercise.

The FireFly Forest is a distracting, calming and interactive audiovisual AR experience that aims to distract, calm, and engage children during venipuncture. By transforming mandatory procedure steps into rewarding, game-like challenges, the experience distracts the patient while supporting the nurse in ensuring a smooth procedure. The experience begins when the patient sits still and focuses on an object in the distance. Then, the AR software detects their stillness and spawns glowing fireflies as a reward for sitting still, coming from the object they were focussing on. This way, any type of viewing direction (Monitor, Curious or Blunter) can experience the fireflies by spawning them from different directions. The fireflies have a mesmerizing, soothing effect, helping the patient relax while the nurse prepares for the puncture.

Just before the procedure, the patient is asked to make a fist to assist the nurse in locating the vein. At this moment, the magical firefly Lumi appears, moving from the patient's fist and drawing their attention away from the procedure. Lumi then guides the patient through a breathing exercise, helping the patient relax their muscles, making it easier to puncture for the nurse. As the patient is focussing on the breathing exercise, the puncture is performed. Then, the patient is rewarded with celebratory firefly rain, reinforcing a sense of achievement while the blood is drawn. Figure 64 explains the different steps over a timeline in more detail.

Mounting the AR headset

	Step	Digital world *What does the patient do and see?*	Physical world *What does the nurse do and see?*
1	**Acclimatising**	The patient has a moment to get used to the digital world and look around freely.	The nurse has a moment to gather the puncture tools. Then, the nurse or Medical Pedagogical Caretakers checks in if the child is feeling well with the headset.
2	**Reward for sitting still**	The patient is challenged to sit still, because then, fireflies will appear. Fireflies spawn in a tree in the direction that the patient is looking at. The visualisation shows three different looking directions (yellow arrows were added as an indication).	If the patient feels well, the nurse (or MPC) asks the patient to sit very still so that fireflies will appear.The nurse applies the tourniquet and cleans the area.
3	**Fist interaction**	Lumi appears and flies away from the fist of the patient. If the patient is looking directly at the procedure, their viewing direction is guided away from the procedure. If the patient was looking away from the procedure already, Lumi appears in that place.	The nurse asks the patient to make a fist.
4	**Breathing exercise**	The patient is following a guided breathing exercise together with Lumi. By default, the breathing exercise takes place 5 times. As long as a fist is being detected, the breathing exercise will loop.	The nurse locates the vein and performs the puncture with the syringe.
5	**Rewarding firefly rain**	The patient has completed the most challenging part of the puncture and experiences a firefly rain show in all magical and bright colours as a reward.	The nurse collects the blood samples and wraps up.

Demounting the AR headset

Figure 64. A timeline showing the different steps of the AR experience.

Design elements

Fireflies

In the designed AR experience, fireflies spawn as a reward for sitting still. Fireflies spawn from trees or other objects that the patient is looking at. The fireflies have a slow glowing pace, creating a calming and mesmerising effect, contributing to capturing attention. The fireflies appear at any time and are not restricted to time limits, therefore it ensures the experience can run for an ‘infinite’ time as it keeps on looping. To top the experience off, the patient is rewarded in the end with a celebratory firefly rain effect in the end.

Prototype limitations
The spawn location of the flies was simplified to being pre-programmed. Also, the fireflies do not actually interact with the user but appear and disappear manually.

Key features
- 🌟 Glowing objects
- 🦫 Main character buddy
- 🔀 Different viewing directions
- 🏆 Sitting still reward
- 🔁 Looping

Lumi

Lumi is a big, glowing firefly that talks to the patient in a positive, reinforcing manner with a friendly, high pitched voice. Once a fist is made, he invites the patient to breathe along. Lumi moves along with inhaling (expanding) and exhaling (shrinking) to guide the patient during breathing.

Prototype limitations
The fist interaction is triggered manually using a button.

Key features
- 😮‍💨 Breathing exercise
- 🌟 Glowing objects
- 🦫 Main character buddy
- 👀 Object moving away from procedure
- 😊 Positive reinforcement
- 🫳 Intuitive controls

Forest landscape

Over 30 different natural objects have been placed in the scene, ranging from 1 to 1000+ instances to provide interesting views. To create more depth and fantasy-like dreaminess, purple fog was added. Small plant objects, such as grass and flowers, move along with the wind at a slow pace, like it is breathing.

Prototype limitations
Due to rendering limitations, trees were kept static.

Key features
- 🌄 Captivating and visually pleasing landscape
- 😮‍💨 Breathing exercise

Calming music and forest sounds

A slowed version of a song was chosen to provide a calming and soothing experience. The melodies repeat themselves, providing a meditative effect. There are not a lot of deep tones and the music is predominantly major key. In the background, there are forest sounds of birds, wind and water, providing a relaxing ambient.

Prototype limitations
The spawn location of the flies was simplified to being pre-programmed. Also, the fireflies do not actually interact with the user but appear and disappear manually.

Key features
🎶 Calming music and nature sounds

AR Pass-through

To still see the original procedure, there is a ‘window to reality’ to the original procedure. At all times, the patient can look in this direction and see the original procedure. It is a static cut to reality, with a gradient towards the digital world.

Prototype limitations
In the prototype, the AR pass-through has a rough cut in a capsule shape, instead of a smooth gradient transition.

Key features
🪡 Show original procedure with pass-through

Figure 65. A list of design elements with their prototype limitations and key features.

Waiting Room Experience: Lumi’s Portal

An engaging pre-procedure experience that distracts children in the waiting room while introducing the FireFly theme.

Concept Development
Lumi’s Portal was created as a concept from the client evaluation session, the ideation phase in the Develop chapter and from feedback from healthcare professionals. While it has not yet been evaluated with the target group, it serves as a foundation for future exploration and potential implementation.

Concept Explanation
Lumi’s Portal is an interactive digital screen experience designed to engage and distract children while they wait in the waiting room. Attention is captured through its big screen, but also through little glowing Lumi’s that hang on the ceiling. When children approach the screen, Lumi will start to guide the child through different interactions:

- **Personal Introduction and Companionship:** Lumi says: “Hi! I’ll be with you the whole time, let’s do this together!”. Lumi’s presence before the procedure ensures that when the child encounters him again in the AR experience, it feels like an ongoing journey rather than an isolated interaction, creating a sense of familiarity and support.
- **Storytelling:** Lumi shares a captivating story about the FireFly world, immersing the child in a playful narrative that shifts their focus from the upcoming procedure.
- **Preparation game:** Through an interactive game, children practice holding still, reinforcing a key procedural requirement in a fun and interactive way.

Intended impact
Lumi’s Portal aims to:

- **Provide distraction** during the waiting period, reducing awareness of waiting room noise and preventing anxiety buildup.
- **Introduce the FireFly theme**, increasing engagement and familiarity with Lumi before transitioning into the AR experience during the procedure.
- **Create positive reinforcement** by encouraging children with kind words, making them feel supported and acknowledged, creating a sense of **companionship**, ensuring that the child is not alone in the experience. This helps shift the dynamic from “me vs. the adults” to “I have a buddy on my side.”
- **Ensure flexibility** by allowing the experience to be interrupted at any moment, accommodating unpredictable waiting times in a clinical setting.

Key features
Key features are (see Figure 66):

- Interactive Touch Screen: A capacitive touch display enables direct interaction with Lumi, allowing children to engage through gestures, touch-based activities, or guided prompts.
- Directional Sound Shower Technology: Highly focused directional speakers ensure that Lumi’s voice and audio cues or music are only audible when a child stands directly in front of the screen, minimizing noise pollution in the waiting area.
- Motion Sensor for Stillness Training: Infrared or optical motion sensors detect subtle body movements, enabling a stillness-based game where children practice holding their arm steady, reinforcing procedural preparation in an engaging way.
- Glowing Physical Lumi Elements: LED-illuminated hanging fixtures designed as Lumi characters provide a soft, pulsing light, drawing attention to the play area while remaining securely out of reach of children, ensuring durability.

Recommendations
Further testing is needed to evaluate engagement, emotional response, and practical feasibility. The effectiveness of the stillness game should be assessed to ensure it truly helps children practice procedural requirements while remaining enjoyable. Technological feasibility must also be explored, comparing screen-based versus projection-based solutions in terms of cost, durability, and hospital integration. Personalization of Lumi’s reinforcement, such as adaptive messaging or voice interaction, could enhance its supportive role. Collaboration with healthcare professionals is essential to align the experience with hospital workflows and ensure a smooth connection between pre-procedure preparation and venipuncture.

Figure 66. The final concept for the Waiting Room Experience: Lumi's Portal, highlighting its key features.

Physical souvenir: Lumi’s Adventure

A Personalized Reward Booklet for Encouragement and Progress Tracking.

Concept Development
Lumi’s Adventure was created as a concept from the client evaluation session, the ideation phase in the Develop chapter and from healthcare professionals feedback. The concept is inspired from a vaccination passport, as recommended by the client. While it has not yet been evaluated with the target group, it serves as a foundation for future exploration and potential implementation.

Concept Explanation
Lumi’s Adventure is a small A5/A6 booklet designed for children who undergo multiple venipuncture procedures, allowing them to track their progress. The booklet is layered for different ages, offering options for varying reading levels, see Figure 67:

- **Sticker Collection:** Children collect different Lumi stickers after each procedure (for younger children)
- **Fun Firefly Facts:** Engaging educational content (for older children that have a developed reading level)
- **Personalized Compliments:** Space for nurses or caregivers to write positive reinforcement messages.
- **Self-Reflection Checkboxes:** Children can mark what they felt went well during the procedure.
- **Emotion Tracker:** A section where children circle an emoji to express how they felt.
- **AR Interaction Record:** A section to circle the animals or objects they spotted in the AR experience.

Intended impact
Lumi’s Adventure Booklet aims to:

- Provide children with a **sense of achievement**, making them feel proud of their accomplishments.
- Create a **lasting and engaging souvenir** through storytelling and collectible stickers, (or even pages) with the potential to expand over time.
- Encourage **positive reflection** after each procedure, reinforcing motivation and emotional resilience for future visits.

Key features

- **Compact Format**: Light booklet in A5 or A6 for easy handling and storage.
- **Durable, Child-Friendly Design**: Printed on sturdy, tear-resistant material.
- **Interactive Elements**: Stickers, checkboxes, and writing prompts for engagement.
- **Layered Content for Different Ages**: Visual sticker-based interaction for younger children; reading more factual content for older ones.
- **Customizable for Hospitals:** Allows integration of hospital logos or specific messaging.

Recommendations
To enhance the impact and accessibility of Lumi’s Adventure, a puncture certificate could be introduced for one-time visitors, ensuring that all children receive a tangible reward, even if they do not return for multiple procedures. Additionally, incorporating a QR code in the booklet could extend engagement beyond the hospital visit by linking to Lumi-themed videos, interactive stories, or an AR-enhanced experience. Moreover, a section could be dedicated to a puncture plan for the child, contributing to a sense of control. Before large-scale printing, it is recommended to conduct a pilot study with the target group to ensure that children understand and engage with the booklet as intended. Lastly, exploring options for printing on recycled paper would contribute to making the booklet a more sustainable initiative.

Figure 67. Visualisation of the A5/A6 booklet of Lumi's Adventure.

Storyboard

In this storyboard, the interaction of the final design is visualised. Lumi's Portal and Lumi's Adventure are displayed in a simplified manner, focussing on their desired effects rather than their details. The purpose of this storyboard was to tell the story of the child, looking at the procedure from their perspective.

The child arrives at the hospital, looking up at a large, imposing building.

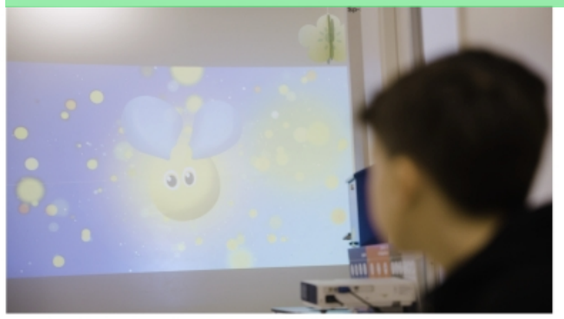
The child walks through the hospital with their caregiver.

They approach the venipuncture department.

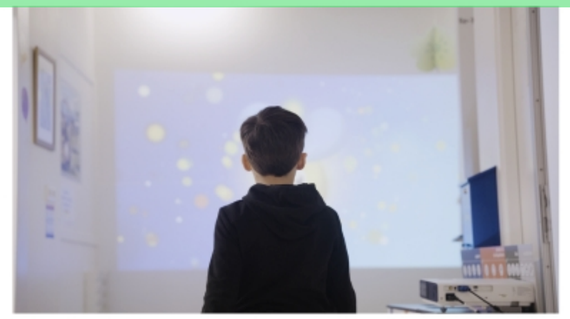
After they have received their waiting ticket, they wait in the waiting room.

There are a lot of background noises, the tension levels of the child rise.

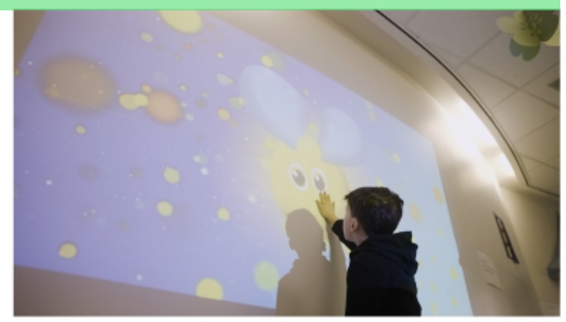
Lumi's Portal



The child notices a big shining object.



He approaches this area of the waiting room.



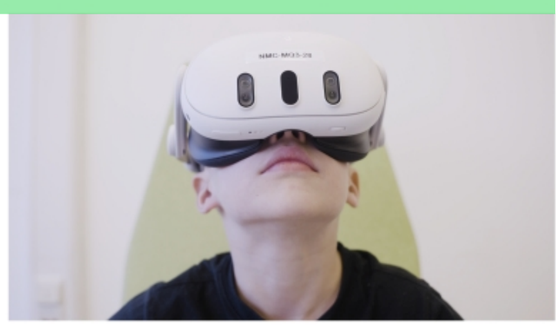
He starts to interact with Lumi, being fully immersed.

He is welcomed by the nurse.

When he sits down the nurse explains him what the procedure will look like.

FireFly Forest

The nurse mounts the AR headset.



The child has a moment to acclimatise.

FireFly Forest

The child sees this 3D environment next to the pass-through of the procedure.

The child is amused by what he sees, and is challenged by the nurse to keep still.

Then, fireflies start to appear from the tree he was focussing on.

In the meantime, the nurse applies the tourniquee.

FireFly Forest

Then she cleans the area and asks the child to make a fist.

Firefly Lumi spawns in the AR world.

The viewing direction of the child is guided away from the procedure.

Lumi invites the child to join a breathing exercise.

FireFly Forest

The child follows along with the breathing exercise.

In the meantime, the puncture is performed.

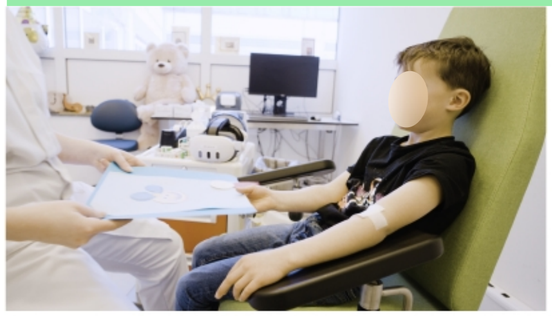
While the blood is flowing, the child is rewarded with a firefly rain.

The child is enjoying the show.

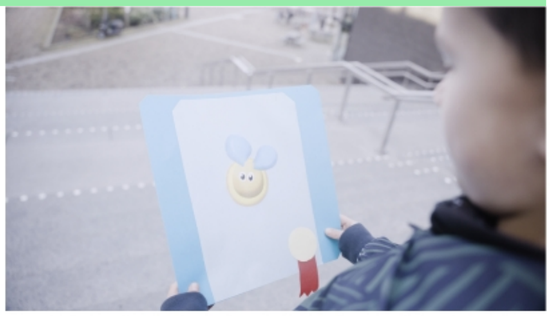
The nurse takes off the headset.

The child looks down and sees the bandage: the puncture is already over!

Lumi's Adventure



The nurse gives the child a reward: a certificate.



The child is proud of his certificate, going home with an accomplished feeling.
NB: This is a simplified version of the Lumi's Adventure Booklet.

Figure 68. A storyboard showcasing the final desired interaction, mapping out when each experience begins.

4.2 Evaluation with target group

How does the target group experience the AR interaction?

Objective

To address the main research question, the final AR prototype was developed. The main research question is:

*How can an AR experience be designed for venipuncture procedures to **effectively distract** children aged 6–12 years, reducing their perception of pain and anxiety while maintaining their sense of being in control?*

Due to ethical constraints with regards to medical related research, no direct measurements of pain or anxiety could be taken. Therefore, the primary aim of this test was to evaluate to what extent the AR experience captures attention and effectively distracts. The venipuncture procedure was simulated using hospital toys, mimicking a clinical environment. The effectiveness of distraction was assessed based on the extent to which children noticed or focused on these objects during the experience. Additionally, the test served to evaluate specific design elements, ensuring their intended functionality. Prior to the prototype testing, questions were stated from the design elements with aligning data collection methods, see Figure 74.
Finally, the test served to obtain feedback from the target group on general appearance and interaction.

Participant recruitment

Six children between the ages of 9 and 11 were recruited for the study, consisting of five girls and one boy. All participants were classmates in the 7th grade of a Dutch elementary school. Recruitment was conducted through the school, and participation was entirely voluntary. Informed consent was obtained from their parents or guardians before participation.

The participants had varying levels of experience with VR technology. One had never used a VR headset before, while others had significant experience, including ownership of a VR headset at home. This variation allowed for insights into how both novice and experienced users interacted with the AR experience and how intuitive the prototype was for first-time users.

Method

Test set-up

This study followed a user experience evaluation approach with a controlled observational setup. The test consisted of the patient, one observer and an acting researcher who acted as a nurse. This 'nurse' simulated a venipuncture procedure using toys that were lined out on Table 1 (see Figure 69), and one hidden item behind the nurse: the yellow cloth. The AR experience ran in developer mode from Laptop 1, whilst live notes were being taken on Laptop 2. The camera recorded footage for data-analysis purposes.

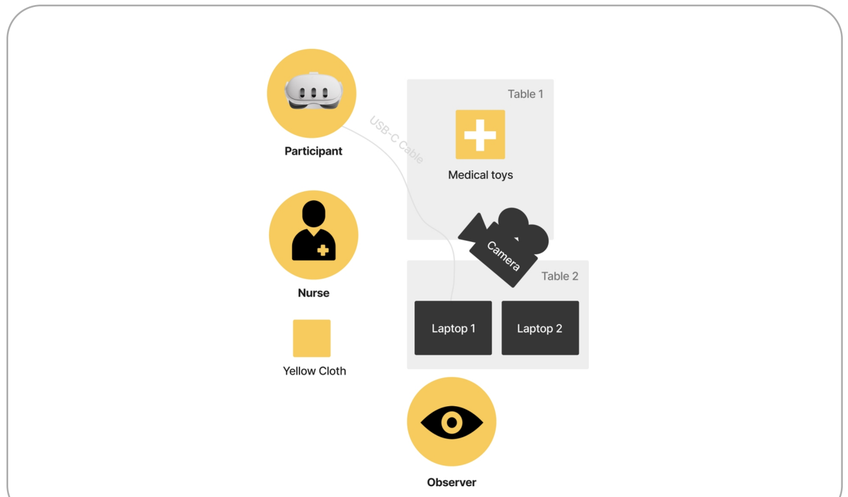


Figure 69. Theoretical test set-up as preparation.

Figure 70. Test set-up in practice, Laptop 2 is not visible on this image.

Procedure steps
To simulate the venipuncture procedure without performing an actual medical intervention, a structured approach was used where the process was mimicked using hospital toys. The study followed these steps, following a three phase structure:

1. Introduction and Acclimatization
The child was welcomed and given a brief explanation on the research and Augmented Reality, simplified as Virtual Reality. They were given time to get used to the VR headset in a white VR room, ensuring comfort before the test began, and they were free to quit the experience anytime.

2. AR Experience and Simulated Venipuncture Procedure
Children were challenged to sit as still, because then fireflies would appear. Significant movement was observe. Meanwhile, a simulated venipuncture procedure was performed by the nurse, using three toys to mimic the clinical procedure:

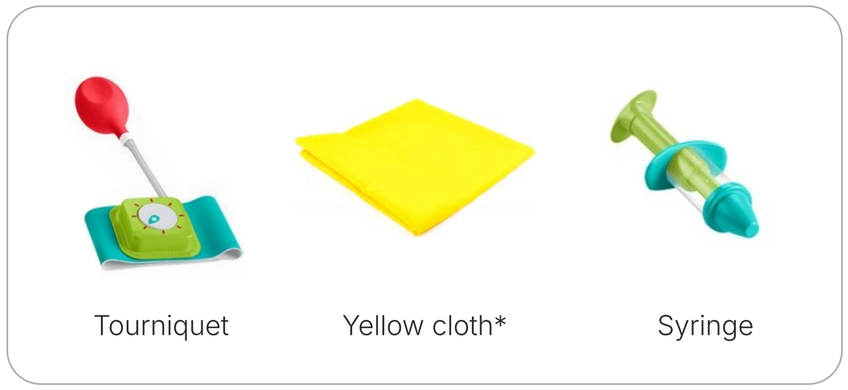


Figure 71. The three different hospital toys that were used in the research.

*The yellow cloth was kept hidden in the pocket of the nurse and not visible on Table 1.

During the procedure, children were asked to make a fist, whereafter an interactive element would appear in the AR world. Their interaction with this element - the breathing exercise - was observed.

3. Post-experience Interviews
After the experience, children were asked an open-ended question about what their initial thought was of the experience and if they could tell something about what they had felt on their arm. They were asked to point out which items were used on their arm on Table 1, not showing the yellow cloth. A semi-structured interview was conducted with the participant to gain qualitative data.

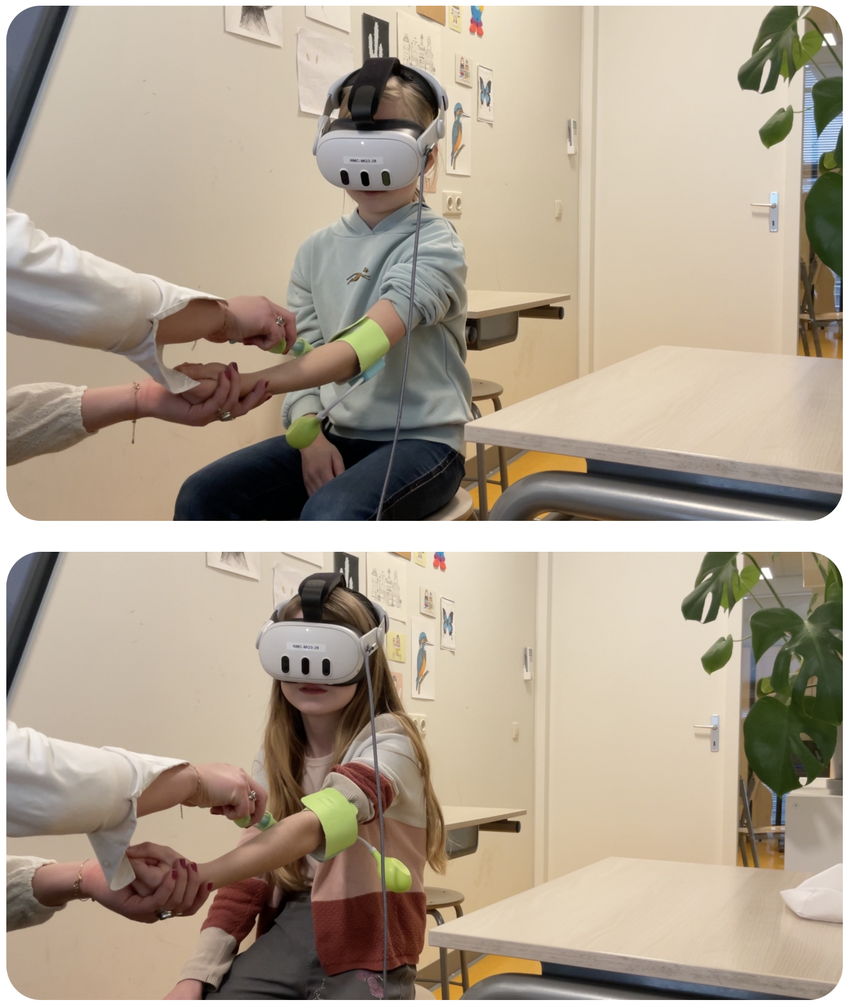


Figure 72. Screenshots from video data at the moment of puncture.

Figure 73. A pass-through view of the procedure.

	Research question	Evaluated component	Evaluation Metrics (Data Collection Methods)
1	To what extent does the AR experience capture attention and effectively distract?	Main Research Question	> Apply three objects on the arm > Ask post-experience open-ended questions about object recall and focus. > Analyse looking direction of screenrecording → Focus shifting between AR and physical procedure
2	How do the fireflies influence the child's ability to sit still?	Design element: Fireflies	Observe the frequency and duration of significant body movements (fidgeting, head turns, etc.)
3	How clear and engaging is the breathing exercise for children to follow effectively?	Design element: Lumi	> Count number of successful inhale-exhale cycles completed by the child during the exercise. >Observe whether children follow the visual or audio cues without additional explanation. > Ask in open interview questions
4	To what extent does the interaction feel intuitive and work without explanation?	General interaction	> Note whether children perform the expected interactions (e.g., making a fist, sitting still, knowing where to look at) without prompts/questions. > Count additional instructions
5	How do the elements (landscape, sounds, fireflies) contribute to a calming effect?	Design elements: Fantasy forest landscape&music	Self-reported feedback on which elements the children found most calming or soothing.
6	To what extent does the child feel like they can control where they look?	Design elements/main research question: Pass-through	Self-reported sense of control, head movement tracking.
7	How attractive is the AR experience (visuals, theme) for the target group?	General appearance	Open questions in post-interview

Figure 74. Theoretical test set-up as preparation.

Data collection and analysis

To systematically evaluate the effectiveness of the AR prototype, research questions were linked to measurable outcomes through structured evaluation methods. Figure 74 provides an overview of how each research question was tested. Data was obtained from live observations, video recordings, screen recordings on the headset, open interview questions and audio transcripts.

Results

The AR experience was evaluated to determine its effectiveness in capturing attention, promoting stillness, and providing an engaging distraction during a simulated venipuncture procedure. Observational data, self-reported feedback, and head movement tracking were analyzed to assess how well children interacted with the experience. The following sections present the findings in relation to the research questions. See Appendix for a more extensive overview of results.

1. To what extent does the AR experience capture attention and effectively distract?

The ability of the AR experience to capture attention and effectively distract was assessed by analyzing whether participants focused on the virtual environment rather than the simulated medical procedure. Three actions were executed on the patient's arm with three different objects. In a post-experience interview, an open question was asked in what they had noticed on their arm. The following answers came forward:

			
Participant	**Tourniquet**	**Yellow cleaning cloth**	**Needle**
P1	"Something was put around my arm"	"I did not see that"	Did not see
P2	"I felt something like velcro"	"Yes I saw that"	Did not see
P3	"I got this wrapped around me"	"Oh yeah there was some cloth, I believe it was yellow" (forgot about in the open question)	Did see
P4	Did see	Did not see	Did not see
P5	Did see	Did see	Did see
P6	"That green thing, it was a bit cold"	"Little bit of tickling.. was it green?"	Did not see

Figure 75. A schematic overview of post-experience questions on the three items that were applied on the arm.

When asked about what had been done to their arm, only two of the six participants recalled the syringe, while most remembered the tourniquet. The yellow cleaning cloth was inconsistently recalled, with some participants forgetting it initially and later recognizing its presence. One participant even thought the cloth was green. From analysing the screen recording observations on the headset, there was footage of seeing the yellow cloth on the screen recording, but without it being reported by participant, indicating effective distraction. None of the children attempted to look beneath the headset, and all remained focused on the AR world throughout the experience. Several participants described the virtual setting as engaging and immersive, stating that they were more focused on the environment than on their arm.

These findings suggest that the AR experience was successful in redirecting attention away from the medical procedure, supporting its potential as a distraction tool in clinical settings.

2. How do the fireflies influence the child's ability to sit still?

The fireflies were designed to encourage stillness by appearing when children remained motionless. Observational data confirmed that all six participants complied with the stillness challenge, with no recorded arm movement. Head movement was minimal, this was recorded by tracking shifts in looking direction, with each movement counted when it exceeded 45 degrees along the XYZ axes relative to the previous position. Movements below this threshold were classified as "slight head movement."
Before the challenge of sitting still was told, the average head movement per participant was 23. When the participants were challenged to sit still, this number became zero, with only one participant having slight head movement.
Participants expressed interest in the fireflies, actively following them within the virtual space. The consistent engagement with the fireflies and the observed stillness suggest that this design element was effective in promoting a motionless state.

3. How clear and engaging is the breathing exercise for children to follow effectively?

The breathing exercise, led by the character Lumi, was designed to guide children through controlled inhalation and exhalation. All six participants engaged with the breathing exercise without requiring external guidance, indicating that the interaction was intuitive. Several participants described the exercise as relaxing, with one child stating, "I like breathing calmly; it helps me feel relaxed." The seamless participation and positive feedback suggest that the breathing exercise was engaging and easy to follow, reinforcing its potential as an effective relaxation tool in medical settings.

4. To what extent does the interaction feel intuitive and work without explanation?
The AR experience was designed to ensure that interactions, such as making a fist to trigger the breathing exercise, felt natural and did not require explicit instructions. Observations confirmed that all participants successfully performed expected actions without hesitation. There was no participant who asked for an instruction during the test. One participant stated, “I just knew what to do when I saw it,” highlighting the intuitive nature of the interaction design. The absence of confusion or the need for external prompts suggests that the AR interface was well-designed, allowing for a smooth and user-friendly experience.

5. How do the elements (landscape, sounds, fireflies) contribute to a calming effect?
The virtual environment was designed to create a soothing atmosphere through its visual and auditory elements. Participants consistently described the AR world as relaxing, with multiple children highlighting the music and colors as particularly calming. One child commented that the forest setting “made me feel at ease,” while another noted that the music contributed to a peaceful ambiance. Some participants suggested additional interactive features, such as moving animals, to further enhance engagement. These responses indicate that the AR environment successfully provided a calming effect, supporting its potential use in reducing procedural anxiety, but with a potential addition to become more interesting overtime.

6. To what extent does the child feel like they can control where they look?
A sense of control over viewing direction was assessed through self-reported feedback and head movement tracking. Most participants reported feeling free to explore the AR environment without restrictions. Observations showed that children naturally looked around within the virtual space, reinforcing their sense of agency. These findings suggest that the AR experience provided a sufficient level of visual control, making it feel engaging and interactive.

7. How attractive is the AR experience (visuals, theme) for the target group?
Children responded vert positively to the aesthetic aspects of the AR experience, describing it as visually engaging and immersive. After demounting the headset, five out of six participants reported as initial thought that they liked it. Several participants called the environment “beautiful” and “fantasy-like,” with particular appreciation for the fireflies, which they described as “cute” and “fun to follow.” Some participants suggested additional themes, such as a flower garden or a library, to maintain engagement for repeated use. One child noted that younger children (ages 5–6) would particularly enjoy the experience, while older children might prefer a more interactive element. The strong positive reception of the visuals indicates that the AR design was well-suited to the target age group.

Figure 76. Participant looking around freely during the acclimatisation step.

Discussion

The results indicate that the AR experience effectively captured children’s attention, encouraged stillness, and provided a calming distraction during a simulated venipuncture. Most participants focused on the virtual environment rather than the procedure, with minimal recollection of medical objects used on their arm. The fireflies successfully motivated stillness, and the breathing exercise was intuitive and engaging. However, conducting the study in a simulated setting with hospital toys rather than real medical instruments presents limitations.

In a real medical setting, the presence of pain and anxiety could of course alter children’s engagement with the AR experience. Physical sensations such as a tightening tourniquet or a needle prick might draw more attention to the procedure, making it more challenging to sustain distraction. Additionally, the clinical environment—characterized by medical staff, equipment, and unfamiliar sounds—may influence immersion differently than the controlled test setting. Future research in a real medical context is needed to determine whether AR remains as effective when medical stressors are present.

Individual differences also played a role in how children interacted with the AR world. While all participants followed the breathing exercise and fireflies, some suggested enhancements, such as increased interactivity or movement options. Some children may find the current experience engaging, whereas other children might benefit from more game-like elements, as one child reported. These insights suggest an option for adaptable AR designs for different age groups and preferences.

Finally, the exact location of the pass-through differed per participant. The headset changed its exact location slightly in the digital world each time it is used, meaning that the exact display of the AR world and pass-through differed per patient. Precise calibration would be necessary for further research.

Conclusion

This study explored the effectiveness of an AR experience in distracting children during a simulated venipuncture procedure. The results indicate that the experience successfully captured attention, encouraged stillness, and provided a calming effect. Most participants focused on the virtual world rather than the simulated procedure, with minimal recollection of the objects used on their arm. Additionally, all participants reported to like the visual appearance of the AR experience. The fireflies effectively motivated stillness, while the breathing exercise was intuitive and well-received. These findings suggest that AR has strong potential as a distraction tool in pediatric medical settings.

However, the limitations of a simulated environment must be acknowledged. The absence of real medical stressors such as experienced or anticipated pain, medical personnel, and clinical surroundings may have influenced engagement levels. It remains uncertain how children would respond to the experience in a real hospital setting, where anxiety and discomfort could alter their interaction with the AR environment. Future research in clinical settings is necessary to determine whether the same level of distraction and immersion can be achieved during actual medical procedures.

Despite these limitations, the findings provide valuable insights into how AR can be designed to support children undergoing medical treatments. The study highlights the importance of balancing interactivity with relaxation, adapting experiences to different age groups, and ensuring engagement over repeated uses. By refining the AR experience and testing it in real medical contexts, this technology has the potential to significantly reduce procedural anxiety, improve the patient experience, and support healthcare providers in delivering more comfortable treatments for children

Takeaways for Design Recommendations

1. Keep It Engaging Over Time

To maintain interest across repeated uses, children suggested additional interactive elements, creating more opportunities for movement, interaction with objects, or evolving game-like features to keep the experience fresh. For instance, an animal running by. However, calming effectiveness needs to be taken into account before developing this feature.

2. Adapt Interactivity for Different Age Groups

The children responded well to the current design, but one child reported that older children may benefit from more complex interactions. Adjustable difficulty levels or optional mini-games could enhance engagement for different age ranges. However, any interaction should not trigger arm movement, a crucial aspect that needs to be taken into consideration for future designs.

It is important to note that in the prototype, the fireflies were not really interacting with the user. Without the prototype limitations, the fireflies would have spawned from a looking direction and should have disappeared on head-movement.

3. Offer Thematic Variations

Some children suggested alternative calming environments, such as a library or garden, to keep the experience enjoyable over multiple medical visits. Offering different themes could improve long-term engagement and reduce repetition fatigue.

These recommendations can guide the development of AR interventions to ensure they remain engaging, effective, and adaptable in real pediatric healthcare settings.

4.3 Evaluation with healthcare professionals

How do healthcare professionals estimate the design's feasibility for implementation?

To assess the feasibility and effectiveness of the AR experience in a clinical setting, an evaluation was conducted with two healthcare professionals: a mental healthcare psychologist and a nurse specializing in venipuncture for children. Their perspectives provide valuable insights into both the psychological aspects of distraction and the practical challenges of implementation in a hospital setting.

Mental Healthcare Psychologist

A psychologist specializing in anxiety management and coping strategies in medical settings provided insights into how distraction techniques can reduce stress and improve a child's sense of control during medical procedures.

Method

An evaluation session was conducted with a psychologist to assess the AR experience and explore its potential impact on children undergoing venipuncture. The session consisted of three parts: (1) hands-on testing of the AR experience, (2) a semi-structured interview to gather targeted feedback on feasibility, effectiveness, and psychological impact, and (3) an open discussion on the pre- and post-procedure experiences. The insights gained from this session were directly incorporated into the final concepts of the pre- and post-procedure experience, and regarding the AR experience, the insights are discussed in following sections.

Stakeholder relevance

Understanding the psychological impact of AR is essential to ensure that it effectively reduces anxiety and enhances emotional regulation. Their expertise helps refine the experience to maximize relaxation while maintaining engagement.

Evaluation

The AR experience was perceived as calming and engaging, with an inviting atmosphere that promotes relaxation. The psychologist noted that the balance of stimulation was well-managed, preventing children from feeling overwhelmed. However, some children might require additional interactive elements to maintain engagement, particularly those with higher anxiety levels or those who prefer active distraction. A key strength of the AR experience is its ability to provide a sense of control by allowing children to direct their attention within the virtual world. To increase this sense of control, it was suggested that more small interaction choices within the AR environment could be beneficial.

Figure 77. Evaluating the AR prototype with a Mental Healthcare Psychologist at the Erasmus MC Sophia.

It was also recommended that prior arrangements be made with the child that help with switching between the physical and digital worlds. For example, it was suggested that nurse can say: "raise your hand if you don't feel well".

The breathing exercise was recognized as an effective tool for relaxation, but the psychologist suggested enhancing it with real-time feedback. This meant that when the child loses attention on the digital world, their attention would again be guided towards the digital world through an interactive element. Next to that, the breathing exercise was triggered by the fist interaction, but a suggestion was to research this into more depth. Therefore this is addressed further in the session with the nurse.

For the physical souvenir, the psychologist had suggested a certificate is a very powerful manner of physical reinforcement, which was translated into Lumi's Adventure Booklet.

Conclusion

The psychological perspective confirms that the AR experience has strong potential as a calming and immersive distraction tool. However, to maximize its effectiveness, additional interaction options, such as **regarding attention** and **adding small choices for contributing to a sense of control**. Future refinements should also ensure **a smooth transition out of and back into the real-world medical setting** to maintain the calming effect. Ultimately, the **trigger and timing for the breathing exercise** need to be investigated further.

Nurse

A nurse experienced in performing venipuncture provided practical insights on how the AR experience fits within hospital workflows and its impact on patient cooperation.

Method

A session was conducted with a nurse to gather practical insights on the feasibility and integration of the AR experience within the venipuncture procedure. The session began with a video demonstration of the AR experience followed by an open discussion on the nurse's needs, opinions, and observations. Key topics included the usability of the intervention (such as the fist interaction), its potential to support workflow efficiency, and any concerns regarding its implementation in a clinical setting. The insights gained from this session were directly incorporated into the final concepts of the pre- and post-procedure experience, and for the AR experience the insights are discussed in following sections.

Stakeholder relevance

Nurses directly interact with children during venipuncture, making their input crucial for ensuring that the AR experience is practical, easy to use, and beneficial for both patients and staff.

Evaluation

The nurse found the AR experience visually engaging and was very enthusiastic about the design. Since many children become tense during venipuncture, making it difficult to find a suitable vein, the relaxing effect of the AR world could help improve procedural efficiency. If the child's arm remains relaxed, the nurse can locate the vein more quickly, making the process smoother for both the patient and the medical staff. The nurse added that the design could be very beneficial if "the AR does the calming" so that she could focus on the puncture.

However, a major concern was time constraints in hospital settings. Since medical staff are often under high pressure, the AR experience must be quick and easy to set up to ensure widespread adoption. If setup is too complex, staff may view it as an additional burden rather than a useful tool. The tool should be implemented in some way in their workflow.

Another consideration was how different children react to medical procedures. Some children are anxious simply because they do not know what to expect, while others have had prior traumatic experiences that make them more fearful. The nurse had suggested that a short introductory video in the waiting area could prepare children by showing them what to expect, reducing uncertainty and fear. This was taken into account in the pre-procedure experience in Lumi's Portal.

A practical improvement suggested was a reward system integrated into the AR experience. If children remain still when everything was going well, they could receive virtual rewards, making the experience more rewarding.

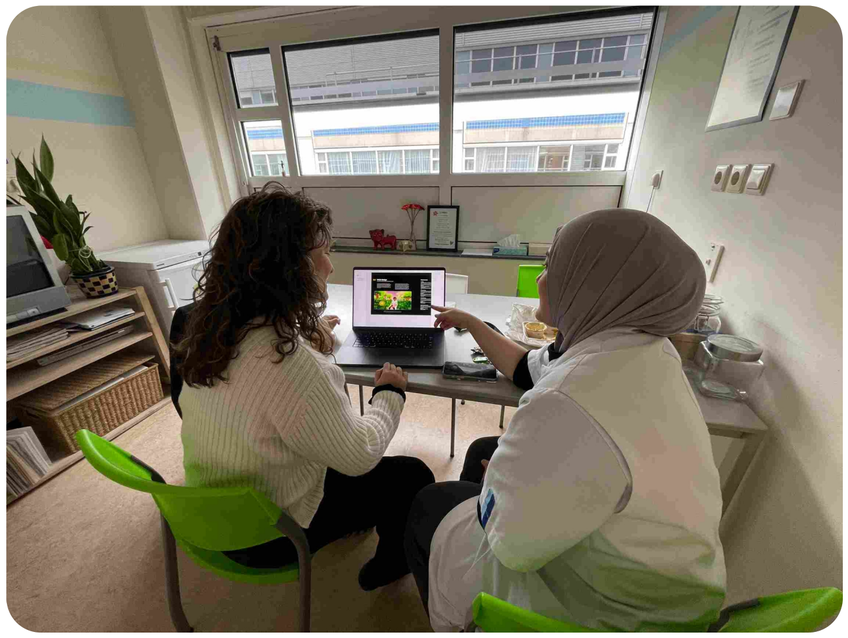


Figure 78. Evaluating the AR design with a nurse at the venipuncture department in the Sophia hospital.

For the fist interaction that triggers the breathing exercise, the nurse indicated that the interaction could work, but not in all cases. Sometimes, locating the vein takes a couple minutes and not always is it necessary to make a fist.

Conclusion

The nursing perspective confirms that the AR experience could be highly beneficial for procedural efficiency, helping children relax and remain still. However, a proven ease of use, quick setup, and seamless workflow integration are essential for hospital staff to adopt the system effectively. Additionally, **introducing an extra rewarding system** during the procedure and **providing pre-procedure preparation in the waiting area** could enhance engagement and reduce fear, as stated by the nurse. Lastly, it was recommended to **research the interaction for the fist further**.

> *Nurse: "What we want as nurses seems well considered in the design. It looks really nice. It looks like a fantasy world, cartoon really well done...it's not just for kids, even I like it! You really listened to us."*

4.4 Design goal evaluation

Does the concept meet the design goal?

To evaluate whether the design goal was reached, each element of the design goal will be elaborated and analysed with prior research and findings. The design goal is:

To create a distracting and calming (AR) experience for children during venipuncture, guiding their attention to an engaging digital world, without hiding the physical procedure, in a way that improves the procedure experience for both the child and the nurse, while being easy to implement in a clinical workflow.

Distracting and Calming
The AR experience successfully integrates key distraction and calming elements. The FireFly theme, interactive glowing objects, guided breathing exercise, and a serene digital landscape work together to reduce stress and anxiety. Observations from prototype testing showed that children were highly engaged with the AR world and focused on interactive elements rather than the simulated procedure. Additionally, the use of calming music and nature sounds aligns with relaxation techniques, reinforcing the effectiveness of the experience. The results suggest that the AR intervention provides an effective form of distraction within the constraints of a venipuncture procedure. Active distraction was achieved particularly through the guided breathing exercise.

(AR) Experience
The AR experience forms the core of the intervention, ensuring an immersive and interactive environment for the child. However, the broader design extends beyond AR alone, with conceptual exploration of the Lumi's Portal waiting room experience and the Lumi's Adventure Booklet physical souvenir to provide a more holistic approach. While these additional elements were not fully developed or tested, their conceptual inclusion acknowledges that effective distraction and comfort should extend beyond the AR headset alone. Future iterations could explore an optimised integration between these experiences to ensure a seamless transition across all phases of the procedure.

Children
The design is developed for children aged 6–12 who experience fear and anxiety related to venipuncture. The FireFly theme, interactive mechanics, and visual style were designed to be engaging and comforting for this age group. Testing showed that children responded positively to the experience, expressing excitement and engagement with the digital world. However, while the concept is suitable for the full 6–12 age range, it is likely that younger children are especially drawn to the playful and animated elements. Older children may still find the interactive aspects engaging but could potentially benefit from a slightly more mature variation of the experience, like Lumi.

Guiding Attention
The firefly mechanics and interactive elements effectively lure attention away from the procedure and toward the digital world. The design encourages voluntary redirection of focus rather than forcing a single perspective. The inclusion of movement-based cues, such as fireflies leading the child's gaze, supports natural and intuitive attention guidance. Testing results showed that children were primarily focused on the AR world and did not actively look at their arms during the simulated procedure, supporting the effectiveness of this feature.

Engaging Digital World
The AR world was carefully designed to be visually appealing and interactive while maintaining a calming atmosphere. The combination of glowing elements, nature-inspired visuals, and dynamic yet slow-moving animations contributed to engagement. Children's feedback indicated that they found the world "magical" and "exciting," reinforcing the effectiveness of the digital environment. However, some children expressed a desire for more interactive elements or additional visual variety, suggesting room for further refinement to maintain long-term engagement.

Without Hiding the Physical Procedure
A key requirement was that the AR experience should not completely hide the real-world procedure but instead allow flexibility in viewing preferences for the Monitor, Curious and Blunter. The use of AR pass-through successfully ensured that the venipuncture process remained visible when desired. However for the tested prototype, technical limitations in Unreal Engine prevented a seamless blending of real and virtual elements, resulting in a hard transition between the digital and real world rather than the intended smooth overlay. Implementing a gradient transition between the real and digital world was thus not possible. Despite this, children reported feeling like they could look around freely and did not express frustration with the visibility of the procedure, indicating that this feature was still functional.

Improving the Procedure Experience
For children, mandatory steps in the venipuncture procedure were transformed into rewarding challenges, improving the procedure experience for both the child and nurse. For instance for nurses, the ability to keep children still and calm was a major benefit. During testing, none of the children moved their arms during the simulated procedure, supporting the idea that the AR experience helps achieve procedural compliance. The child was accompanied by Lumi the FireFly, who rewarded the child for doing well, ensuring positive reinforcement and accompanying them during difficult procedure moments.

Easy to Implement
Implementation feasibility was a crucial requirement from the client, and the design made efforts to balance complexity with practicality. The AR experience itself requires minimal setup and can run on a standalone Meta Quest 3 headset, eliminating the need for external tracking systems. However, challenges remain in training staff to operate the experience smoothly.

Clinical Workflow
For the AR experience to integrate seamlessly into hospital workflows, it must be efficient, non-disruptive, and adaptable to varying procedure durations. The final design allows for flexibility in duration, meaning children can engage with the experience whether their venipuncture lasts a few minutes or over an hour. The passive nature of the breathing exercise also ensures that no active user input is needed, being an ongoing interaction on a constant 'loop', making it easier for medical staff to administer. While the concept fits well into the workflow, further evaluation in a real medical setting is necessary to determine whether any practical constraints arise.

Final Evaluation
The final design meets the core objectives outlined in the design goal. The AR experience is both distracting and calming, effectively guiding attention away from the procedure while still keeping the physical procedure visible. The procedural experience is also improved for nurses, as they benefit from reduced patient movement. However, implementation challenges remain, particularly in integrating the AR experience smoothly into clinical practice. Additionally, the waiting room and post-procedure elements remain conceptual, meaning their full impact on the overall experience is unknown. Finally, Lumi is designed for children 6-12 years but might be less appealing to the older range of the target group.

4.5 Feasibility, desirability and viability

How feasible, desirable, and viable for real-world adoption is the AR solution?

Feasibility

Technology

The final prototype was developed using Unreal Engine 5.3 for the Meta Quest 3 and relied on manual controls and manual pass-through calibration. To automise those controls, key interactions such as head movement tracking and fist-based interactions need to be further researched, developed, tested, and fine-tuned by an AR developer. However, these features are already possible with today's technology, meaning their implementation is a matter of refinement rather than feasibility. At the Erasmus MC, the available AR headset is the Pico 4, which is similar to the Meta Quest 3. Therefore, an AR developer could adjust the software without major changes.

While a smooth transition between the physical world (pass-through) and digital world was not feasible within Unreal Engine, this is possible with existing Artificial Intelligence (AI) technology. AI-powered segmentation can automatically detect and isolate the venipuncture procedure within the real-world view, enhancing the integration between virtual and physical elements.
Technology Readiness Level (TRL) 9 has already been reached for real-time AI segmentation, which is actively used in AR applications. By using AI, the physical venipuncture procedure could be precisely segmented and overlaid into the digital environment, ensuring a seamless transition between real and virtual environments and allowing for automatic pass-through calibration. This means that the exact location of the pass-through in the digital world would therefore automatically align with the physical world.

Clinical workflow usage

The AR experience is designed to be standalone, requiring minimal setup to fit seamlessly into the clinical workflow. The FireFly experience involves just two steps for the nurse: (1) securing the headset on the patient and (2) allowing a brief acclimatization period to assess the child's comfort and potential cybersickness. This simplicity ensures feasibility in a busy hospital setting.

Practical challenges

While the AR experience is technologically feasible, several practical challenges may hinder its adoption in a clinical setting. Healthcare professionals may experience a "technological barrier", as introducing a new digital tool could disrupt their established workflow, a concern that was mentioned by the client.

Even if this barrier is overcome, there is no guarantee that nurses will actively incorporate the AR headset into their routine, especially considering that existing distraction tools are already unused in the venipuncture department.
Additionally, the headset comes with logistical challenges, requiring regular charging, software reliability checks, and troubleshooting to prevent technical failures during procedures. Furthermore, hygiene concerns must be addressed through strict cleaning protocols to ensure compliance with hospital sanitation standards.

Desirability

Child/patient and nurse

Desirability examines how well the AR experience aligns with the needs and preferences of stakeholders involved. The desirability of this AR experience was evaluated through user testing with children and an evaluation session with a nurse. In the AR experience, mandatory procedure steps are transformed into engaging and rewarding challenges. Through this positive reframing, the concerns of both the child and nurse are met. For the child, the procedure could turn into an interactive game-like experience, improving the likelihood of executing procedure steps better, which is beneficial for the nurse. The presence of a supportive buddy character (Lumi) reinforced the idea that the child was not alone in the experience, providing positive reinforcement. Nurses who evaluated the product expressed thereby great enthusiasm, seeing its potential to streamline their workflow if the product was securely proven to be effective. Because if the AR experience effectively calms children, it could allow them to focus more on the procedure itself rather than spending time on emotional reassurance, ultimately making the venipuncture process more efficient. However, the nurses that experience a technological barrier would need to address this barrier first before they would envision using the AR.

Parents/caregivers
From a parental perspective, the AR experience could offer reassurance by providing a structured distraction, potentially helping children stay calm and cooperative during venipuncture. This may ease parental stress, as they would not have to take full responsibility for comforting their child.

The hospital
For the Sophia, if the AR proves effective in minimizing puncture times, it could significantly contribute to hospital efficiency while improving patient experiences. Which eventually, could make it a cost-effecient alternative.

Viability

Regarding viability, this AR experience has potential applications beyond pediatric venipuncture. During peer testing, adults also responded positively, suggesting that it could be beneficial for a wider demographic. The core mechanics of the AR experience—grounding patients in reality while offering a distraction, turning mandatory procedure steps in rewarding AR interactions—could be extended to other medical procedures where relaxation and controlled attention are necessary. This adaptability could lead to broader implementation across different departments, making the experience a scalable and valuable tool for healthcare environments. Scalability is further discussed in the next section.

4.6 Scalability and long-term scope

How scalable is the final design, and what are its long-term application prospects?

Scalability

The AR experience designed for pediatric venipuncture has scalability potential, as its core mechanics—real-time distraction, guided breathing, and interactive engagement—can be adapted for various medical procedures and patient demographics. While the current prototype is tailored to children aged 6–12 undergoing venipuncture, the same principles could be applied to other minor medical interventions where anxiety reduction and procedural stillness are crucial.

Expanding to other procedures

The distraction method can be used in vaccinations, IV insertions, wound dressing changes, and dental procedures, where fear and discomfort are common in both children and adults.

From an evaluation session with a nursing consultant specializing in pediatric bladder catheterization, additional potential use cases emerged. Similar to venipuncture, children undergoing catheterization often experience fear and distress. Some children prefer to retain a sense of control by seeing parts of the procedure, while still benefiting from a distraction. The consultant saw potential for how this AR intervention could be applied within their department, particularly as a tool to reduce anxiety and improve patient cooperation during catheterization procedures. This further supports the adaptability of the experience for different pediatric medical contexts.

Adaptability to different age groups

While the current design is child-focused, customizing interaction levels, themes, and engagement mechanics could extend its use to younger children, teenagers, and even adults in settings where pain and anxiety management are needed.

Hospital-wide integration

The AR experience could be standardized as part of pediatric procedural care, allowing healthcare facilities to adopt it for multiple departments, such as pediatrics, emergency care, and outpatient clinics.

Beyond the Erasmus MC

With proper software optimization and training protocols, the experience could be replicated and scaled to other hospitals, if there is access to compatible AR hardware (e.g., Meta Quest, Pico 4).

Long-term scope

Sophia Children's Hospital is undergoing a major transformation, with plans to reopen its newly designed facility in seven years (Dierckx, personal communication, 2024). This offers the opportunity to align the AR experience with the hospital's future vision, where Comfort Care becomes the new standard of care. Also, as healthcare moves toward patient-centered and technology-integrated solutions, a long-term vision could be that AR-assisted procedural distraction becomes an integral part of standard care rather than an optional intervention.

Advancements in AR Technology

Currently, AR headsets are relatively bulky (compared to a phone) and require manual adjustments. However, future developments are expected to lead to lighter, more streamlined, and possibly wearable AR solutions. Companies like Meta are actively working on integrating AR displays into smart glasses, suggesting that more practical, user-friendly versions will soon be available (Williams, 2023).

Integration of AI

Advancements in AI-driven adaptive environments could improve the seamless transition between the real and virtual worlds, making the transition from into and out of the digital world smoother and more user friendly. AI could also decrease the workload for the AR developer by generating new 3D environments, ensuring the experience remains interesting for returning patients overtime.

Addressing the shortage in healthcare personnel

Self-guided interventions like AR distraction could help ease this pressure by reducing the need for continuous emotional reassurance from nurses and MPCs. By enabling children to manage their own anxiety through interactive distraction, AR could make procedures run more smoothly, requiring less staff involvement in calming patients and improving efficiency in an already overburdened healthcare system.

Considering these advancements, AR technology could play a crucial role in the future of pediatric care, enhancing both patient experience and procedure efficiency.

4.7 Implementation roadmap

What are the key steps and considerations for implementing the AR distraction tool in a clinical setting?

The implementation of the AR distraction tool was discussed in collaborative sessions with the client and a healthcare psychologist, where different approaches were explored to integrate the system within a medical setting efficiently. The primary objective of these discussions was to outline feasible pathways for deploying the AR experience while considering practical constraints, regulatory requirements, and hospital integration challenges.

Client session

The client preferred to look at a pragmatic and rapid implementation, emphasizing the importance of distinguishing the AR tool from therapeutic interventions, as this classification significantly impacts the implementation timeline. If the system does not claim to have a therapeutic effect, it does not require formal medical validation under regulatory frameworks. This distinction allows for a faster and more flexible deployment strategy without the need for extensive clinical research and approval processes. Conversely, if the AR tool were to be positioned as a therapeutic intervention, a lengthy research and approval process would be necessary, including compliance with METC (Medical Ethical Committee) regulations, randomized patient trials, and formalized consent procedures.

Mental healthcare psychologist session

In collaboration with the healthcare psychologist, key considerations for effective clinical adoption were also identified. The psychologist recommended starting implementation in an optimal scenario, focusing on children undergoing their first venipuncture experience who have no prior exposure to needles. This approach would allow for a more controlled assessment of the AR system's effectiveness before expanding its use to children with existing anxiety related to medical procedures. Furthermore, successful integration within the hospital setting requires strong collaboration with nursing staff, ensuring that the system does not disrupt established medical workflows but instead enhances the overall patient experience. A dedicated point of contact within the healthcare team who understands both the AR tool and medical procedures was highlighted as a crucial factor for long-term success.

Based on these discussions, two primary scenarios were identified for implementation. These scenarios provide structured decision-making pathways, allowing stakeholders to choose between a pragmatic deployment approach or a scientifically validated research-driven implementation.

Scenario 1: Pragmatic and Rapid Implementation
This scenario prioritizes fast deployment based on the premise that the AR system does not require medical validation as long as it does not claim to have therapeutic effects. That being said, this way of implementing has lower costs compared to a research-based approach.

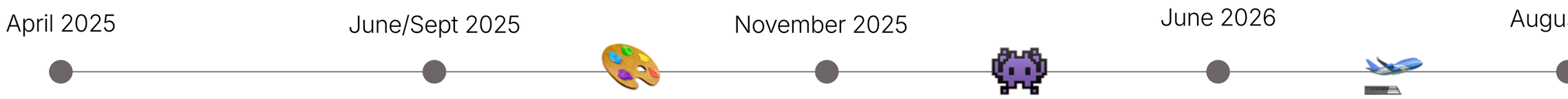
Scenario 2: Research-Oriented Implementation
If a more scientific validation approach is pursued, the implementation process extends significantly due to the requirement for formal medical research activities such as ethical approval, randomized trials, and comparative studies. This scenario follows a PhD research trajectory, requiring approximately 1.5 years for full validation.

As the client emphasized the urgency of implementing the AR experience as soon as possible, the first scenario—a pragmatic and rapid implementation approach—was chosen as the basis for the implementation roadmap. This approach prioritizes immediate deployment while ensuring feasibility within the hospital's operational and financial constraints.

The following figure (on the next page) provides a structured overview of the implementation steps, stakeholders, and key milestones. For the fastest and most practical implementation, the Pilot Phase could serve as the final step. However, to ensure the intervention is both effective and sustainable, further research and development is recommended.

Additionally, an extra step was included to support future scalability. This step was not explicitly discussed with the client, but serves as means of inspiration for long-term implementation potential.

Implementation roadmap



	Securing funding	Improving the concept	AR Development	Pilot phase
🎯 Goal	Secure financial resources to fund AR development and implementation.	Improve the concept with stakeholders and professionals.	Develop and refine the AR experience before the pilot phase.	Run a pilot phase in the hospital to detect final adjustments.
👥 Stakeholders	Project team, Client (hospital representatives), Funding organizations (Stichting Sophia, grant), AR development partners	Psychologists specializing in mindfulness-based/relaxation interventions, children (target group), healthcare professionals, KAR Sophia (Children's Advisory Board)	AR development team, UX designers & interaction specialists, Pediatric psychologists (for feedback)	Hospital management, IT & technical support, Nursing staff from venipuncture department, Addressing a professional who bridges the gap between healthcare and AR
📈 Steps	• Identify funding opportunities (Stichting Sophia, grants, hospital budget). • Submit funding applications. • Define AR project scope and key design requirements. • Select an external AR development partner.	• Co-creation session with stakeholders: children, healthcare professionals and KAR Sophia. The goal here is to evaluate design, generate new ideas and to evaluate the pre- and post-procedure experiences. • Evaluate and improve the design with psychologists specializing in mindfulness-based interventions. • Combine insights into action points for the AR development phase.	• Develop interactive AR features and user interface with smooth pass-through transitions. • Conduct usability testing in non-clinical environments. • Iterate based on feedback from UX experts & pediatric specialists.	• Give AR training to small group of nurses. • Test the design in medical context and collect real-world patient and hospital staff feedback. • Combine findings into action points for further improvement.

st 2026 | March 2027 | June 2027 | January 2028 | January 2029

Final design development	Clinical Deployment	Full implementation	Further implementation
Finalise the AR design and develop Lumi's Portal and Lumi's Adventure.	Train hospital staff and integrate AR into hospital workflows.	Expand deployment hospital-wide and refine the AR system.	Expand the design to other hospitals.
AR development team, UX designers & interaction specialists, Pediatric psychologists (for feedback), Interaction designer (for pre- and post-procedure)	Medical staff (nurses, doctors) Venipuncture department manager IT support team (for deployment)	Hospital management IT & technical support Nursing staff, Department Managers from different departments	Hospital management from other hospitals, Medical staffs, IT and technical, Procurement and finance teams, Hospital safety and legal team, Department managers
• Finalise the AR experience, implementing findings from the pilot phase in the final AR experience. • Investigate the budget for the pre- and post-procedure experience, making a plan. • Develop and build pre- and post-procedure experience.	• Train nurses and staff on how to introduce and operate the AR tool. • Feedback session with nurses on how the AR tool could be implemented in their clinical workflow. • Gather feedback from medical staff and adjust deployment strategy.	• Deploy the AR system across multiple hospital departments. Explore opportunities for adults. • Start pilot testing in different departments. • Adjust technical and usability aspects as needed.	• Deploy the AR system across multiple hospitals. • Research and develop different strategies for different hospitals. • Adjust technical and usability aspects as needed.

Figure 78. Proposal for an implementation roadmap, following pragmatic and rapid implementation, the final step is the Pilot Phase step.

5

Conclusion

This chapter reflects on the outcomes of the project, discussing its limitations, recommendations, and broader implications. Section 5.1 Discussion addresses key challenges encountered during development, including methodological constraints, design considerations, and implementation feasibility. It also provides recommendations for future research and design improvements.

Following this, the conclusion summarizes the project's key findings, evaluating how the final design aligns with the research question and design goal. The chapter concludes with insights into the potential impact of AR distraction in a medical setting and suggestions for future development and implementation.

5.1 Discussion

This project explored the potential of Augmented Reality (AR) as a distraction tool for children undergoing venipuncture. Through research, design iterations, prototype testing and evaluation sessions, the FireFly Forest experience demonstrated promising results in engaging and distracting children. However, several critical reflections must be addressed regarding the study's scope, methodological limitations, and broader implications for implementation in a real medical setting. This discussion is structured around key aspects of the project, highlighting its limitations and recommendations.

Effectiveness of AR Distraction in a Medical Setting

Limitations

The AR prototype demonstrated potential for effective distraction in a simulated, non-medical setting. However, the effectiveness of the experience under real-world hospital conditions remains uncertain. Factors such as heightened anxiety, the presence of medical staff, nocebo effect and parental influence may impact engagement and pain perception. The study did not assess how children would respond when facing an actual needle, which could alter their behavior and willingness to interact with the AR environment.

Recommendations

Future research should conduct clinical testing in a real hospital setting to validate whether AR distraction functions as intended during venipuncture. Observing children in a medical environment will provide insights into how external stressors influence engagement and whether adjustments are needed to maintain and attract attention under these conditions.

Sustaining Attention and Engagement Over Time

Limitations

Findings suggested that AR can effectively capture children's attention, but questions remain about its long-term engagement, especially for frequent hospital visitors. Additionally, if a child repeatedly looks at the procedure instead of focusing on the AR world, should the system intervene more frequently? Should there be multiple reward layers? Next to that, could the theme become monotonous overtime? Answers to these questions did not fit into the timeframe of the project, therefore several recommendations are listed.

Recommendations

To maintain engagement, the AR environment should evolve over time, incorporating new interactive elements and varying reward mechanisms. This could be done using AI, allowing for automatically generated 3D environments exploring different themes. Gamification strategies, such as progressive challenges or unlockable features, could also enhance long-term interest. However, excessive stimulation might also encourage movement, which is undesirable during venipuncture. Balancing these factors remains an important consideration for further development. The system should also detect when a child is predominantly looking at the procedure and attempt to redirect attention through additional visual or auditory cues.

Appeal to Different Age Groups

Limitations

Children aged 9–11 responded positively to the aesthetics of the FireFly Forest, but it remains unclear whether the design appeals to all children, particularly older boys. The theme may be perceived as too childish for some, limiting engagement.

Recommendations

Future iterations of the AR experience should explore customization options to appeal to a broader age range. Offering different themes, color schemes, or interaction styles could make the experience more adaptable to individual preferences. Testing with a more diverse age group could further refine the visual and narrative aspects.

Sense of Control Through AR

Limitations

The AR design aimed to provide a sense of control by allowing children to choose their focus during the procedure. However, this effect was difficult to measure outside of a real venipuncture scenario. Without actual medical stressors, it remains unclear whether the ability to shift focus between the AR world and the real-world procedure effectively translates into increased autonomy and reduced anxiety.

Recommendations
A more targeted study should assess how children perceive control when using AR in a medical setting. Measuring whether children feel more empowered, calmer, or more cooperative when given the option to focus on AR elements could provide valuable data on the effectiveness of this approach. Other than that, small choices could be added in the AR experience, contributing to a sense of control.

Sample Size and Stakeholder Inclusion

Limitations
The final test group was relatively small, consisting of only six children between the ages of 9 and 11, and only one nurse was interviewed. Additionally, parents were not involved in the evaluation, which limits insights into their perspective on the feasibility and desirability of the AR experience.
Recommendations
A larger-scale study involving a wider age range of children, multiple healthcare professionals, and parents would provide more reliable, quantitative data. Including parents would be particularly valuable in understanding how they perceive AR as a tool to reduce their child's distress and whether they would support its implementation in clinical practice.

Fist Interaction as a Trigger

Limitations
Currently, the breathing exercise is triggered by making a fist, aligning with a typical step in venipuncture. However, this interaction may not always naturally occur, or being in the field of view of the patient, potentially causing delays or confusion. Additionally, the timing of this exercise in relation to the actual puncture requires further evaluation.
Recommendations
Exploring alternative procedural triggers, such as the application of a tourniquet or nurse-controlled activation, such as voice-recognition, could offer more reliable timing. Comparative testing of different triggers would refine the experience, ensuring seamless integration within clinical workflows.

Transition Between Real and Digital World

Limitations
The final prototype features a relatively abrupt transition between the physical pass-through and the digital world. A more gradual and seamless transition might be crucial in fostering a calm and comforting experience for children, thus influencing overall anxiety reduction and immersion positively.
Recommendations
Future development should focus on improving the transition between physical and digital environments, potentially incorporating gradual blending techniques or advanced segmentation methods. Enhanced visual transitions could improve user comfort, immersion, and overall effectiveness. However, this needs to be further researched.

Guided Relaxation & Breathing Exercises

Limitations
The breathing exercise was integrated to help children regulate stress and maintain muscle relaxation before the procedure. However, its effectiveness was not fully tested in a medical setting, and its impact on actual anxiety reduction remains unclear. Additionally, the exercise was designed without direct input from a mindfulness or pediatric psychology professional, meaning that its structure and pacing may not be fully optimized, especially not for young patients with varying anxiety levels.
Recommendations
Future studies should evaluate the effectiveness of mindfulness techniques, such as guided breathing, within the AR experience. Collaboration with mindfulness professionals, child psychologists, or pediatric specialists could help refine the breathing exercise to ensure it aligns with evidence-based relaxation techniques. Personalization features, such as different breathing rhythms or relaxation exercises, could also be explored to tailor the experience to individual patient needs.

Augmented Virtuality vs. Augmented Reality

Limitations

Technically, the experience designed is Augmented Virtuality (AV) rather than traditional Augmented Reality (AR), providing primarily digital content with limited real-world visibility through pass-through. This approach could limit the user's sense of physical grounding, but further research needs to be done to verify this.

Recommendations

Comparative studies between AV and traditional AR setups would clarify the advantages and disadvantages of each. Determining whether children benefit more from increased immersion (AV) or a stronger physical grounding (AR) can guide future technological implementations.

Technical Development & AR Implementation

Limitations

The AR prototype was developed without prior AR development experience, meaning that its technical execution and optimization were limited. While the prototype demonstrated the core interaction principles, there is significant potential for improving performance, visual quality, and user experience. Key areas requiring further refinement include the transition between real-world and digital elements, motion tracking accuracy, and seamless integration of interactive features. Additionally, the current implementation relied on manual controls, and further research is needed to explore more intuitive, automated interactions.

Recommendations

Future development should involve collaboration with an experienced AR developer to improve the technical execution of the experience. This includes optimizing real-time rendering, ensuring smooth interactions, and improving the calibration of AR elements with real-world positioning. Additionally, integrating AI-powered segmentation and improved hand tracking could create a more natural and immersive AR experience.

5.4 Conclusion

This project explored how an AR experience can be designed to effectively distract children aged 6–12 during venipuncture procedures, reducing their perception of pain and anxiety while maintaining their sense of being in control. The research resulted in FireFly Forest, an AR experience that engages children through interactive fireflies, a guided breathing exercise, and a reward system, turning mandatory procedure steps into engaging challenges.

To effectively distract, the design uses visual engagement, interactive elements, and calming audio to capture the child's attention and shift focus away from the procedure. Testing in a simulated non-medical setting confirmed that children were drawn to the AR world and responded positively to the interactive fireflies. However, as the prototype was not tested in a real medical context, the true impact on pain and anxiety perception remains uncertain. Future research in clinical environments is necessary to validate its effectiveness under real conditions.

The design also aimed to maintain a sense of control by allowing children to shift their focus from AR environment to the physical world. However, measuring this aspect was difficult without a medical setting where children experience real anxiety. The balance between immersion and awareness of the procedure should be further explored.

The study also highlights the importance of pre-procedure and post-procedure interactions in optimizing the effectiveness of AR distraction. Introducing a comforting element, such as Lumi's Portal, in the waiting room can help distract from tension build-up. Other than that, it also introduces the theme, allowing for better engagement and recognition during the AR experience. Moreover, a positive post-procedure experience, such as Lumi's Adventure booklet (the physical souvenir), can reinforce a sense of accomplishment and provide continuity in care for children who undergo repeated venipunctures. These additional interactions enhance the overall patient experience, ensuring that the designed interaction is not only effective during the puncture but also contributes to helping children process and cope with the procedure before and after it.

While the AR experience shows strong potential as a distraction tool, further development is needed to refine its implementation in clinical workflows. After all, the majority of the distraction tools is not used in the Sophia and therefore an effective strategy on implementing the AR intervention needs to be research.

Future iterations should investigate long-term engagement, test different age preferences, and assess whether the system remains effective and interesting for children undergoing frequent procedures. Moreover, collaboration with medical professionals is essential to ensure that the experience aligns with hospital protocols and patient needs.

Overall, this project provides a foundation for using AR in pediatric venipuncture procedures. With further refinement and clinical validation, FireFly Forest could become an effective tool to improve children's venipuncture procedure experiences while supporting workflow of healthcare professionals.

Personal reflection

To finalise this report, I would like to reflect on the work I have done. For me it was the first time to design for a medical context. I am intrigued by how many people (healthcare professionals) were willing to talk to me about their expertise and on how we could improve venipuncture procedures. This hospital structure of professionals and academical research has really served as a solid foundation for my project. Moreover, I live next to the Sophia hospital, allowing me to frequently visit the venipuncture department. I think I have visited the venipuncture department at least ten times. Just to sit there and think. Great source of inspiration.

Then there was another place I visited quite often: The XR Zone at the TU Delft. I visited this place to develop the AR experience in Unreal Engine. The learning curve for Unreal Engine was incredibly steep—at times, even impossible to tackle on my own. Because AR development is still so new, there simply wasn't enough documentation available to execute this project autonomously. I often found myself deep in online forums, looking for answers that didn't exist. Thankfully, I had the support of AR experts in the XR Zone at TU Delft, whom I am incredibly grateful for. Many times, my questions were met with, "You could not have known this," "You cannot find this online," or simply, "That is not possible." It was frustrating to realize that some of my ideas weren't feasible—not because they weren't good, but because the technology just wasn't there yet.

Letting go of some of my fantasies for the AR experience was tough. As a designer, I love thinking big, imagining boundless possibilities, and pushing creative limits. But at some point, I had to shift my focus from what I wanted AR to be to what I could actually make work. I spent months in the XR Zone, fine-tuning interactions, connecting nodes, debugging endlessly (for days even), and still coming to the conclusion that my prototype was never going to be flawless. Accepting this limitation was a turning point—it allowed me to see the AR design as something bigger than my own technical skills in Unreal Engine.

This realization led me back to the aspects of interaction design that I really enjoy: testing with children, designing the waiting room experience, and crafting the physical souvenir. Especially when the children were so enthusiastic about the design, I felt like I had finally reached the underlying purpose of the project. That's when I fell in love with it again. (Cheesy, I know.)

And if I'm being honest, I fell in love with it most when the project was nearing its end—when I made my final video. That was a moment where I got to explore my passion for storytelling and audiovisual design. Incorporating AR pass-through into the video was a technical challenge, but seeing it come together was a rewarding feeling. wanted the video to trigger emotion—to tell the story of an anxious child navigating a stressful medical experience.

In the end, I am proud of what I've created. The journey was full of obstacles, but those challenges shaped the outcome. I hope this project serves as a starting point for future research, design, and real solutions for children in hospitals.

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