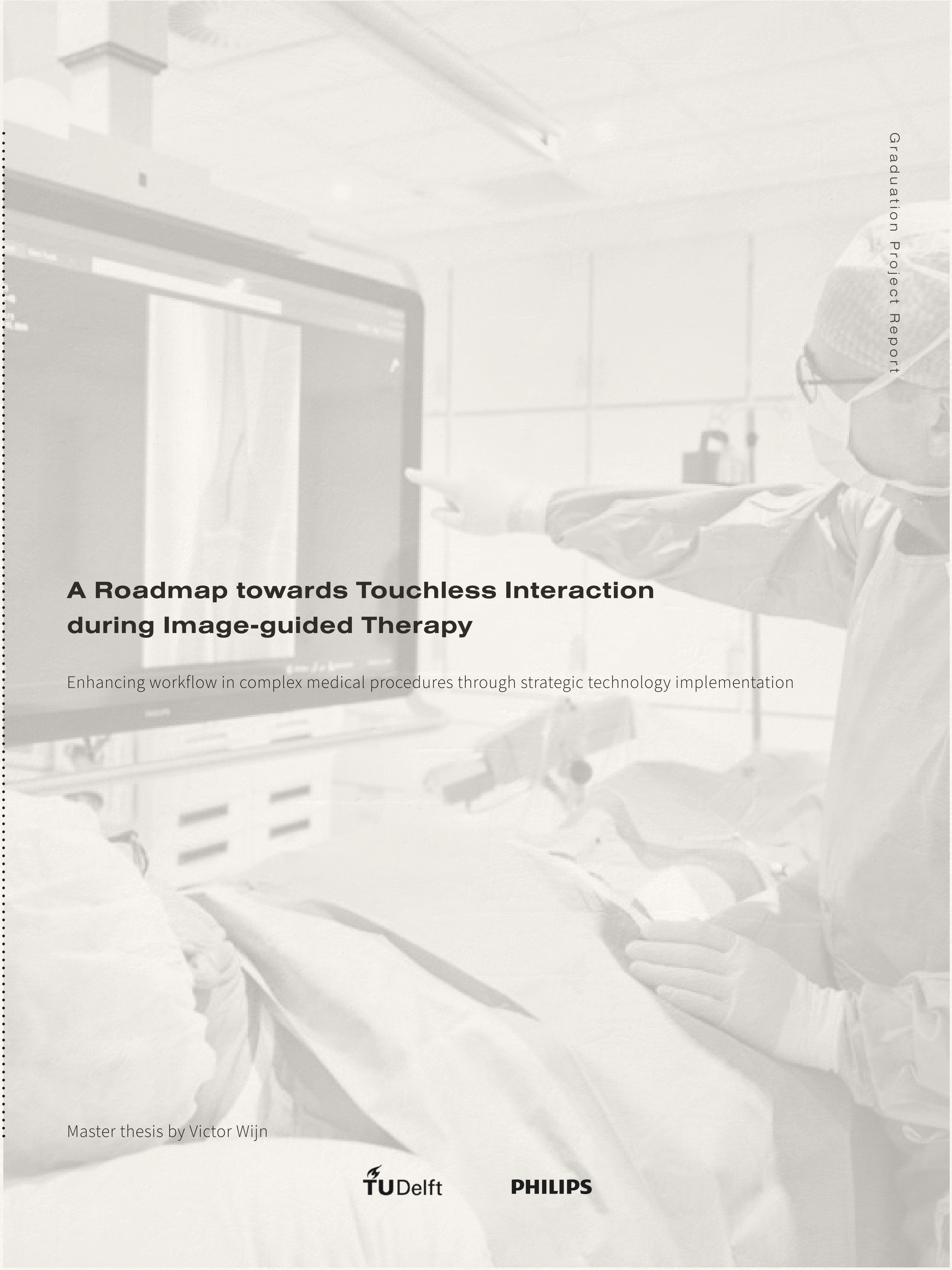


Graduation Project Report

A Roadmap towards Touchless Interaction during Image-guided Therapy

Enhancing workflow in complex medical procedures through strategic technology implementation

Master thesis by Victor Wijn

TU Delft PHILIPS

June 24th, 2021
Master thesis - Strategic Product Design
Faculty of Industrial Design Engineering
Delft University of Technology

Author
Victor Wijn
Student number - 4369564

Graduate committee
Chair - Prof. Dr. Ir. R. H. M. Goossens
Faculty of Industrial Design Engineering
Human-Centred Design Department

Mentor - PhD. M. Li
Faculty of Industrial Design Engineering
Applied Ergonomics and Design / Human-Centred Design Department

Company mentor - Ir. V. Buil
Royal Philips – Experience Design
Senior Technical Consultant

Acknowledgements

This report finalises my master's degree in Strategic Product Design at the TU Delft. Looking back at the years of studying at the Industrial Design engineering faculty, I must say that it was a lot of fun. I am very happy with all the opportunities that I got. This inspirational environment allowed me to develop myself both professionally and personally (a complete personal reflection can be read in chapter 07-5 and Appendix N). Meeting new people, designing together, and inspiring each other motivated me and allowed me to establish myself as a designer. Additionally, I am very thankful for the exciting graduation assignment that I did for Philips Experience Design. In the past months, in which I was motivated to apply all the experience from my education, I have been working really hard on this thesis. Therefore, I am proud to present my final graduation report.

First of all, I would like to thank my supervisors that guided me along the way. Richard Goossens, thank you for the critical and insightful feedback during the sessions we had. I appreciate all the advice, freedom and trust you gave me on the approach of this thesis. Meng Li, thank you for the big amount of enthusiasm, flexibility and support during the coaching of my project. I valued our honest conversations, your perspective and your support on a personal level. Finally, Vincent Buil, thank you for the weekly support and help during this fantastic in-practice learning experience at Philips. Additionally, thanks for the talks during lunch, coffee breaks and all the other fun moments at the office in Eindhoven.

Additionally, I would like to thanks all the colleagues at Philips Experience Design for their expertise, new perspectives, contribution, feedback and fun. I am grateful for the fantastic experience that you were part of. Additionally, I want to give special thanks to the people who were willing to contribute to my thesis by being open for interviews, brainstorming sessions, and discussions that added value to the outcomes of this project.

My family and close friends were also very important throughout this projects. Thanks for always supporting and encouraging me to keep going during graduation in times of a pandemic. I appreciate you listening to my struggles sometimes, yet also celebrating every milestone with me.

Last but not least , I want to thank friends and fellow students that have played a role in my time as a student. You made the previous six years a part of my life that I won't forget.

Enjoy reading!

Victor Wijn

Executive summary

Often bottlenecks in Image-Guided Therapy procedures come down to significant considerations, like sterility and hands-busy situations. However, touchless UI technologies provide solutions in many ways. Interactional properties are gathered from literature and previous studies from Philips. Technologies like eye-gaze, voice control and gesture sensing are expected to minimize the number of mistakes made and time lost because of inefficiencies.

The future context of IGT is explored by doing creative trend research to get an idea of the technologies, trends, and developments in the future healthcare landscape. Additionally, current interactions of IGT procedures are explored to find insights that lead to opportunities for improving these procedures. A resulting design vision is created to provide a design goal and boundaries.

To gain a deeper understanding of the end-user, a research model is developed to validate the opportunities found in the exploring interaction analysis and prioritize value drivers for touchless interaction. The research model is based on a semi-structured interview combined with a workshop that is conducted with multiple stakeholders with four different perspectives of the context of IGT. The findings can be translated into design requirements, guidelines and challenges that provide a holistic overview of the user's needs and desires.

Several design implications are provided that resulted from the ideation brainstorm. By giving an overview of these concepts and their functional benefits, the value for implementing is addressed. Synthesizing these concepts into an implementation strategy that aligns with the future vision is essential before translating these ideas into future scenarios. The future scenarios in this chapter address the alignment with the developing healthcare landscape and related initial horizons of the roadmap. At the end of this chapter, several strategic elements form the foundation of a preliminary prototype of the roadmap to achieve the future vision.

By validating and assessing the different elements of the roadmap, a deeper understanding can be derived, and qualitative results are integrated into the roadmap. A final iteration is made on the alignment of this resulting overview going into the alignment with the company Philips. Then several chapters are included in the report to make it a holistic and academic project. A conclusion is given to answer the research questions. The discussion touches upon the relevance of the research within this academic context. The recommendations go into valuable future research propositions. The limitations of this research are presented, and the way these are minimized is explained.

Practical guide

In order to support the reader of this thesis in understanding the structure but also the content of this report, this practical guide is established. It presents some practical information on the definition of some keywords and specific abbreviations, used in this thesis report, is given. Additionally, the lay-out of the conclusions for every chapter in which the main building blocks of this project are addressed to support storyline towards the design deliverable.

Keywords

Image-guided therapy – A medical suite in which minimally invasive surgery is possible through advanced technological support of multiple systems. The medical team in this context executes complex procedures by navigation through your arteries based on real-time imaging.

Value-based care – A philosophy of delivering optimal care for the patient while reducing the costs of healthcare. Therefore, there is a focus on the optimal care for the patient.

Service proposition – An innovation or service intended to make the customer attracted and adapted to a product or service.

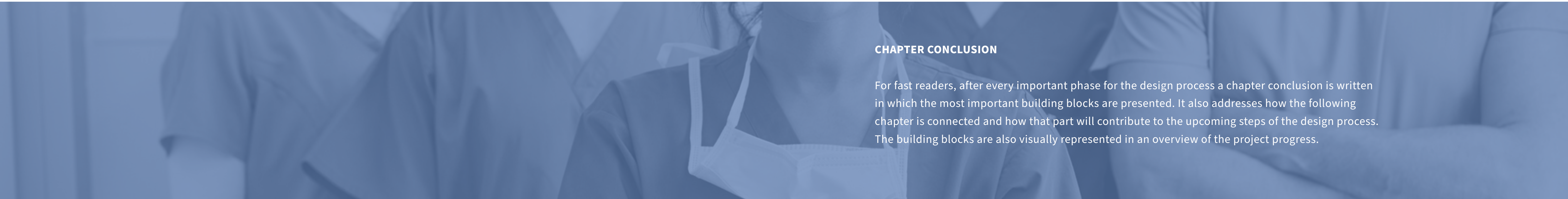
Value driver – A property that is valued to a certain extend when it is embedded in the product or service. In this project we address several interactional value drivers that indicate the desired properties of an interaction.

Strategic roadmap – A mapping of future-oriented strategy that touches upon the implementation of concepts, context changes in the future, several service propositions, etc. .

Opportunity area – A defined scope where an opportunity is established. These address the value for improvement and are based on insights from analyses.

Abbreviations

IGT	Image-Guided Therapy	IC	Interventional Cardiologist
UI	User Interface	HCI	Human-Computer Interaction
PCI	Percutaneous Coronary Intervention	HI	Human Interaction
OR	Operation Room	AI	Artificial Intelligence



CHAPTER CONCLUSION

For fast readers, after every important phase for the design process a chapter conclusion is written in which the most important building blocks are presented. It also addresses how the following chapter is connected and how that part will contribute to the upcoming steps of the design process. The building blocks are also visually represented in an overview of the project progress.

Word count 22994

Table of contents

01 INTRODUCTION

This chapter introduces the background and relevance of the subject of this graduation project. First of all, an introduction of the company Philips is given to get an idea of where this assignment originated. Then a concrete description of the problem is provided to get familiar with the topic of this project. In this part, several research questions are given that represent the foundation of the literature review. At the end of this chapter, an outline of the approach of this project is delivered.

01 - 1 **About Philips**

The company Philips is a leader in health technology around the world. They focus on improving people's lives by providing innovative solutions and better healthcare outcomes through the health continuum. The health continuum (see figure 1.1) touches upon healthcare through healthy living, prevention, diagnosis, treatment and home care. The company uses the newest technologies to provide the best-integrated solutions for innovating clinical applications and improving people's lives. Philips' expertise ranges from "diagnostic imaging, image-guided therapy, medical IT applications, patient monitoring, home care systems and consumer health applications" (Philips, 2019a).

Philips Experience Design

Philips Experience Design is one of Philips's departments that helps achieve its primary goal by constantly driving innovation for its products and services by design. A core value that always should be taken into account is a human-centred design approach. Experience design is a department responsible for all aspects of the user experience for all Philips products and solutions, in all stages; from innovation to market: product design, UI design, service design, communication, packaging, design strategy, innovation, etcetera, are design stages in this part of the company.

Within Philips Experience Design, one of the departments is Image-Guided Therapy (IGT). This department focuses on a relatively new medical environment that enables patients and healthcare workers to increase satisfaction by providing less invasive and more efficient healthcare procedures. Nowadays, one of the focus areas of the IGT department is on improving the User-Interface (UI) interaction in this complex medical context.

Quadruple Aim

To achieve the requirements of specific innovations made by the company, a strategic focus is introduced. This focus is called the 'Quadruple Aim' framework (Philips, 2019b). This aim has been used regularly by an organisation to optimize the implementation of innovation within the health system. At first, this framework started as the 'Triple Aim'. "The 'Triple Aim' was a framework that had been developed by the 'Institute for Healthcare Improvement' that describes an approach to optimize health system performance" (Berwick, Nolan, & Whittington, 2008). This framework consisted of the three following goals: 1) improved patient experience of care, 2) improving population health, and 3) reducing costs. However, since the experience of the healthcare staff significantly adds to the overall quality of care (Bodenheimer & Sinsky, 2014), this is included in the Quadruple Aim of Philips (see figure 1.2).

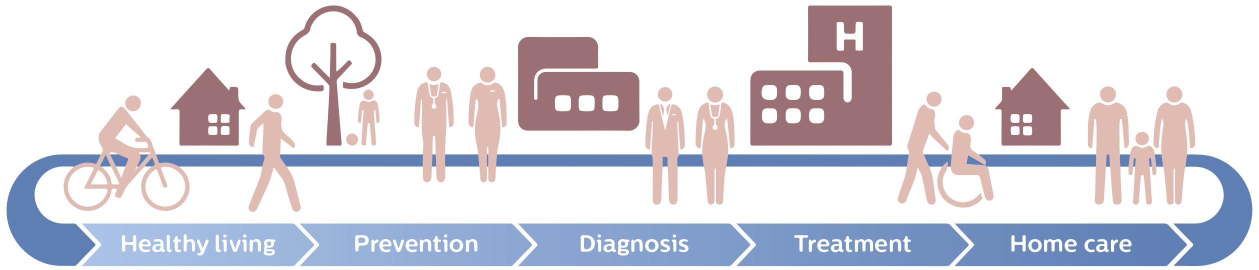


Figure 1.1 - The health continuum of Philips

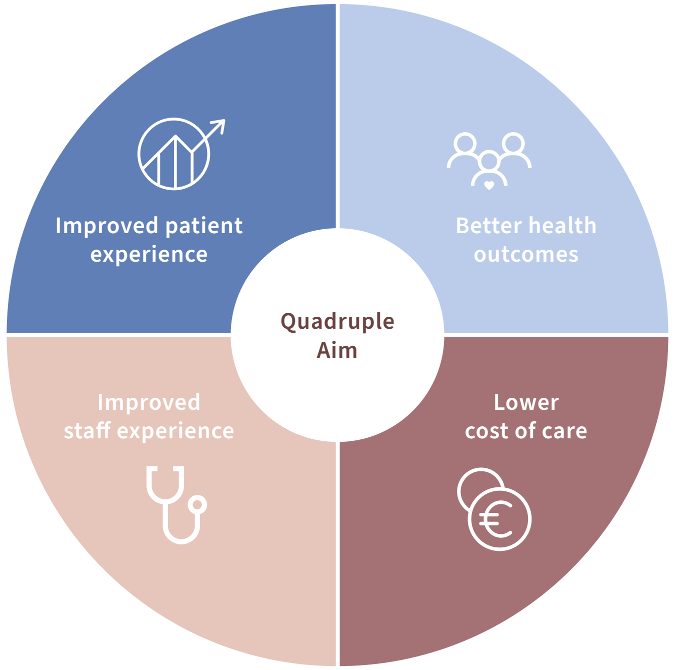


Figure 1.2 - The quadruple aim framework of Philips

01 - 2 **Assignment introduction**

This graduation project focuses on exploring the technological possibilities of touchless interactions in the medical environment of Image-Guided Therapy. In this medical environment, touch-based interaction such as physical controls, touch screens, and mouse is often problematic when the hands are busy treating the patient. Also hygiene constraints play a strong role, which hamper touch-based interactions due to wearing gloves, tedious cleaning protocols, plastic covers over touchscreens and controls, and so on. This could result in inefficiencies and errors caused by colleagues doing the interaction.

Philips is exploring touchless interaction to address these issues. An advanced form of touchless interaction that can be given is that Philips is exploring Mixed Reality. However, this technology is still quite complex, making it less applicable in several situations. Therefore, Philips is exploring alternative solutions to tackle this problem. There is much development in possibilities with User Interaction (UI) techniques like Eye-gaze, Speech interaction and Gesture sensing. When these can be combined efficiently, it is expected that this provides good alternatives for specific situations. This way, there is room for a broad spectrum of new possibilities in the area of innovative interaction solutions in a hospital.

Since a hospital is a very broad context, this project will mainly focus on the possibilities in a specific use case (PCI) during Image-Guided Therapy (IGT). This is a relatively new surgical domain that focuses on minimally invasive surgery. The technology provides clinical solutions in nine different ‘suites’: a coronary suite, a vascular suite, a neurological suite, a oncology suite, etcetera. Philips uses the Quadruple Aim (the improved quality of care, the improved patient experience, the reduced costs, and the improved experience of the medical staff) to guide its innovation in healthcare. Therefore, it is helpful to take this aim into account as a guideline for this graduation project.

Since this is a multi-user environment, it contains much equipment, and there are many different stakeholders and manufacturers, this context is quite complex. A lot is happening simultaneously, and everything has to be sterile due to the earlier mentioned hygiene constraints. However, this complexity allows for good opportunities to improve the performance of the execution of medical procedures happening in IGT.

The most important stakeholders in this context are mainly multiple doctors and nurses and, in most cases, one patient. This patient is usually seriously ill and in need of specialized care or surgery.

This graduation project aims to map opportunities and barriers of combinations of touchless interaction solutions in the specific context of IGT. Therefore, it is essential to document a strategic foundation so Philips can use this knowledge as guidance to develop its technical capabilities to exploit these UI innovations. This way, they can improve their design solutions and drive innovation for touchless interaction in Image-Guided Therapy.

01 - 3 Approach

The design goal of this project is to construct a strategic roadmap that will deliver concrete insights and provides guidance in the implementation possibilities of touchless UI innovations in this healthcare domain. It will touch upon workflow integration, stakeholders, potential barriers, resources and alignment with Philips' support.

Since the outcome for this project will be a roadmap, the theory of the book 'Design Roadmapping' by Simonse (2017) is used in this project. This theory is used to design for future-oriented strategic challenges or objectives. By synthesizing trends and technological developments, values and ideas come together in time-paced horizons (see figure 1.3]. This design theory supports an organizational mindset for innovation through visually substantiated horizons. It is built upon three phases: a value mapping phase, an idea mapping phase and a pathway mapping phase.

An iterative design process is established by combining this theory with the double-diamond design method (Design Council, 2005). This model represents the leading theory behind a general design process that is introduced frequently at the faculty of Industrial Design Engineering at the TU Delft. This iterative principle is based on diverging and converging while taking design steps. The main phases described in this model are: 'Discover, Define, Develop and Deliver'. The initial two phases are primarily about exploration and scoping and the last two stages are about ideation and execution.

Since my approach is inspired by and based on the combination of both theories, an iterative, future-oriented, strategic design process can be described. This way, the design project adds value through alignment with Philips' resources and vision. This design path results in my approach, visualized in figure 1.4. The first two phases (UNDERSTAND and EXPLORE) inquire important considerations and contextual factors through, e.g. interviews, observations, a literature study. This part ends with a future vision. The subsequent phases (IMAGINE and DESIGN) creatively probe possibilities within the design boundaries and context. Through iteration and synthesis, ideas will be developed into concepts. The last phase (DELIVER) introduces a final roadmap in which concepts, insights and perspectives come together and are visually captured with an innovative perspective.

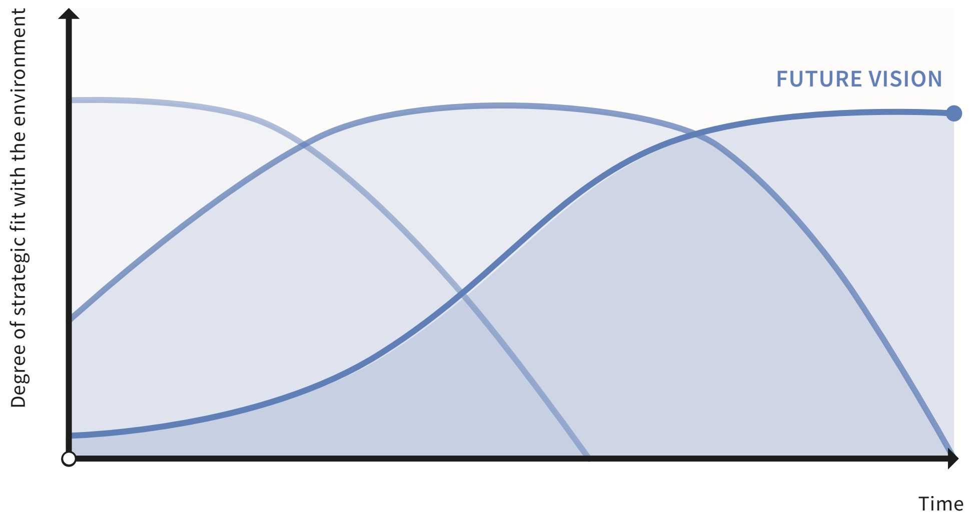


Figure 1.3 - Strategic life cycles of the design roadmapping theory of Simonse (2017)

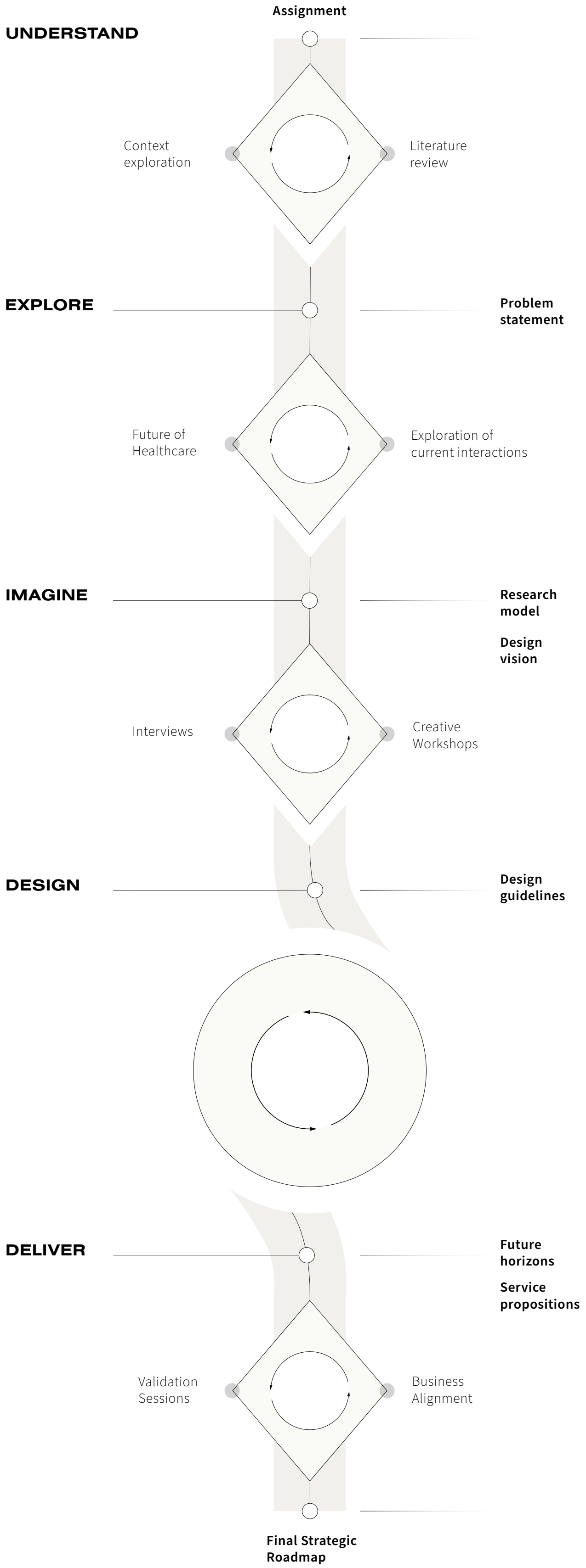


Figure 1.4 - Visual representation of my personal design approach

02 UNDERSTAND

This chapter creates a theoretical understanding of the subjects within this thesis. Starting with a brief explanation of the complex environment of IGT to create an initial foundation of important assets and goals for treatment. Followed by a literature review to academically substantiate the situation for which a strategy can be designed. Within this review, a combination is made of existing literature resources and previous projects of Philips. At the end of this chapter, everything comes together in an opportunity definition that presents a main research question and several sub-questions.

02 - 1 **Contextual understanding**

Philips is the global leader in IGT. This medical specialisation provides integrated solutions that allow for laparoscopic procedures. Since healthcare outcomes are optimized, this business area is of high value to hospitals. These medical procedures run on several systems and devices that are integrated into a special operating room. In collaboration with healthcare providers, care delivery is optimized, total medical costs are reduced, and clinicians are supported to help their patients better so they can walk out of the hospital the same day on average.

“Image-guided therapy is using minimally invasive techniques that allow us to do what surgery used to do, or maybe facilitate new procedures that were never possible before.”

– Atul Gupta, MD - Chief Medical Officer, IGT – Philips

During these interventions, a specialized medical team consisting of multiple stakeholders works closely with Philips’s newest technological devices and systems. These complex procedures are followed and guided real-time via on-screen imaging modalities. This way, technology-enabled, optimal care can be provided for many different interventions. These clinical demands, challenges and complexities can be very specific and patient-dependent. To give an idea of the possibilities of IGT, a portfolio is created consisting of 7 clinical suites. These clinical suites, in which IGT plays a significant role, are given below (see figure 2.1).

Coronary suite – This clinical department is mainly about Percutaneous Coronary Interventions (PCI). By providing a range of diagnostic and therapy tools, effective treatment can take place.

EP suite – This department contains procedures to treat patients with Artificial Fibrillation (AF) that have an increased risk for stroke, dementia, heart failure and death.

SHD suite – This clinical department is about procedures having to do with structural heart diseases. An example of a complex procedure within this suite is Transcatheter Aortic Valve Replacement (TAVR).

Vascular suite – This suite mainly includes endovascular procedures, like Peripheral Artery Disease (PAD) in which revascularisation is done when blood flow is not fulfilled appropriately.

Neuro suite – Procedures that are happening within this suite consider the smallest intracranial vessels for treating medical issues like ischemic strokes.

Onco suite – Minimal invasive oncology interventions get executed within this suite. This provides multiple significant benefits for cancer patients.

Spine suite – Precise procedures for spine surgery are considered in this department. Before, spine surgery would be open surgery, but, nowadays several outcomes can be achieved in a minimal invasive way.

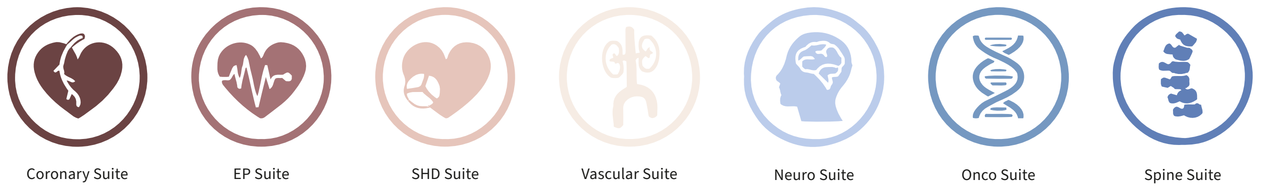


Figure 2.1 - The clinical suites where IGT can be applied

To facilitate high precision and effectiveness for all these procedures, integrated devices, systems, technologies and assets are expected to perform well. A brief overview of the most important systems, devices, assets, and functionalities is shown below (see table 2.1).

IGT systems, devices and assets	Function
FlexArm (C-arch)	Flexible arm that can move and rotate around the cathlab to facilitate imaging functionalities.
Patient table	The central table on which a patient lies when he/she is undergoing an IGT procedure.
FlexVision	The main screen that provides feedback and guidance during IGT procedures for doctors.
TouchScreen Module	A touchscreen that is attached to the patient table on which several functions can be operated.
Control panel (Axsys Motion)	A control panel with buttons that is used to move for example the FlexArm.
Intravscular Ultrasound (IVUS)	A frequently used application to provide ultrasound imagery and run analyses inside the arteries.
iFR	A frequently used application to provide pressure analyses inside the arteries for identifying lesions and calcified areas.
Control room	Separate room in which a technician operates the FlexVision lay-out and several applications .

Table 2.1 - A brief description on the IGT systems, devices and other assets

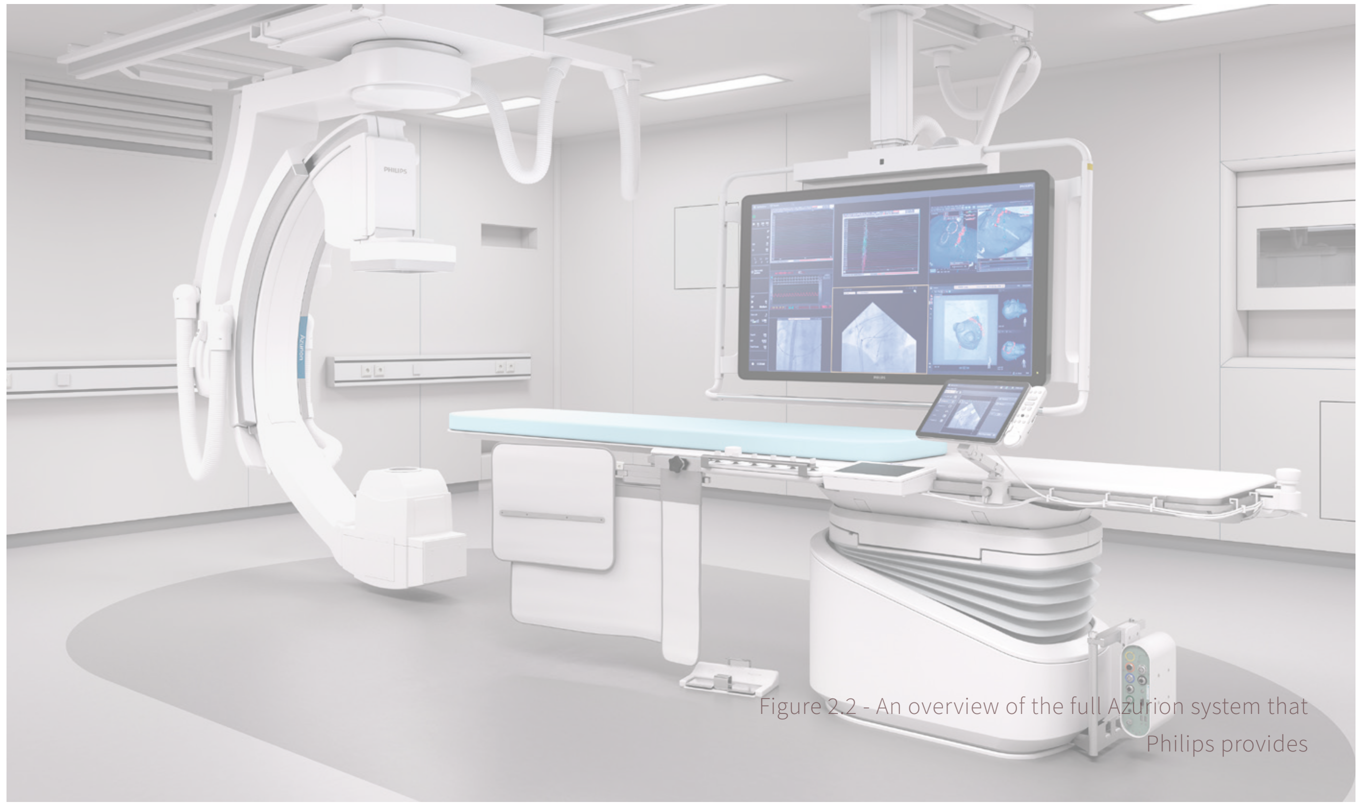


Figure 2.2 - An overview of the full Azurion system that Philips provides


Figure 2.3 - A photo of an IGT procedure, taken from the control room

02 - 2 Literature review

Image-Guided Therapy

Initial work in the field of IGT has shown the importance of a decrease in the total costs and an improvement of the experience of the patient and the healthcare workers during minimally invasive surgery. The term minimally invasive surgery is generally defined as “a surgical procedure that allows your surgeon to use techniques that limit the size and number of cuts, or incisions, that they need to make.” (Jewell, 2018). Research shows that, in general, minimally invasive surgery is considered safer and more comfortable. Additionally, the recovery process takes less time, and therefore, a patient spends less time in the hospital when comparing it to conventional surgery. This allows for more cost-efficient clinical care with high-quality outcomes (Siddaiah-Subramanya et al. 2017; Helmberger et al. 2013; Jewell, 2018). Therefore, these values contribute to the relevance of optimizing procedures that are executed in the context of IGT.

Over the years, the growing interest in care delivery through IGT has become apparent. It is a high-growth, and profitable market (Philips, 2017) expected to keep growing marginally in the upcoming decade towards a market size worth 5.8 billion dollars by 2028 (Grand View Research, 2021). With the launch of the Azurion, procedures in this context can be done more efficiently. With all Philips systems working together, an improved operation can be realized. Imaging, calibration and diagnostic systems alongside each other allow the medical staff to carefully analyse the disease, treat the problem and assess and evaluate the outcome. Systems that are used regularly are given in a separate IGT introduction chapter (Flexvision, C-arch, Intrasight, Syncvision, IVUS, iFR, etcetera).

The consistently developing interest in a better quality of care provided by IGT drives innovation for improving (pre- and post-)procedure time, better health outcomes, patient experience, and healthcare staff experience (Bodenheimer & Sinsky, 2014). “In 2014, this Quadruple Aim was suggested as a framework to optimize healthcare system performance” (Arnetz et al. 2020).

Since this graduation project focuses on the workflow of a specific procedure in the IGT context, inefficiencies within this procedure are interesting to look at. These inefficiencies are often related to the complexities in the environment of IGT.

Sterility

In this medical environment, touch-based interaction such as via keyboard and mouse is often problematic when the hands are busy treating the patient or other cases that have to do with hygiene constraints. "Sterile covers enable the direct use of interaction devices, e.g. joysticks, touchscreens, and control panels, in clinical routines" (Mewes, 2017). However, this often results in inefficiencies and errors caused by delegated colleagues doing the interaction, strict cleaning protocols, and wearing gloves. Additionally, cleaning protocols to prevent bacterial contamination during surgery after checking a computer takes a long time (Cronin & Doherty, 2019). According to Gallo (2013), this can take up to 20 minutes, sometimes adding one full hour to surgical procedures.

Communication problems

As mentioned before, often, colleagues in the operation room (OR) are delegated to execute a task. However, since a lot is happening simultaneously in this environment, it can cause communicative problems. O’Hara et al. (2014) provides an example in which surgeons commonly request other members of the surgical team to manipulate images under their instruction. “While it can succeed, it, too, is not without complications.” (O’Hara et al. 2014). Additionally, research shows that direct control of image data is necessary for surgeons to mentally “get to grips” with what is going on in a procedure (Johnson et al. 2011). A possible complication is the constant background noise happening during an IGT procedure. This results in complicated communicative interactions between, for example, sterile and non-sterile staff (Benzko et al. 2015; Johnson et al. 2011; Mentis et al. 2012).

Multi-user environment

As an effect of the complex procedures done in IGT, there are many different stakeholders present with specific tasks. Generally, these are the stakeholders directly involved when treating the patient: the Interventional Cardiologist (IC), the Fellow IC (F), the Sterile Nurse (S-N), the Circulating Nurse (C-N), the Control Room Nurse / Technician (CR-N), and the Patient (P). For the specific tasks, they execute see table 2.2. The lab layout while this procedure is happening, is given in a schematic overview (see figure 2.4). This overview indicates the multi-user environment. The actual amount of surgical staff needed is decided according to the complexity of the procedure. With all these people having their separate tasks to support the IC in reaching the overall objective, a certain level of complexity is inevitable.

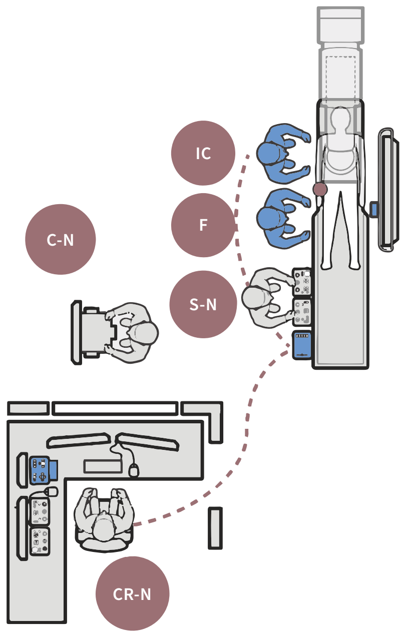


Figure 2.4 - An overview of the setup and stakeholders in an IGT operation room

Interventional cardiologist (IC)
This is the lead operator who does the procedure and gives orders to the other stakeholders in this context.

Fellow IC (F)
This is a stakeholder that assists the cardiologist in the sterile field. Sometimes this is the main operator under guidance of the IC.

Sterile nurse (S-N)
This is a person that assists the IC and the F in the sterile field. Tasks are handing off equipment and controlling the bed, C-arm and basic volcano operations.

Circulating nurse (C-N)
This is a non-sterile nurse who logs the procedure, fetches the equipment from storage and registers the used medication and equipment together with the CR-N.

Control room nurse / Technician (CR-N)
This nurse or technician is in the control room (a separate room of the operation room) monitoring HEMO (blood related values of the patient), and operating basic actions of the IGT systems.

Table 2.2 - An overview of the stakeholders in an IGT operation room and their roles

Limited space

Looking at pictures of an IGT OR in reality, looks messy and hectic (see figure 2.5). Most of this space is used by all the technological application running and supporting the surgery. Additionally, a sterile area is marked on the floor. This is an important region that has to be avoided by non-sterile people or instruments. This causes limitations regarding lack of space for interaction, movement, positioning and other activities (Benzko et al. 2015).

Time pressure

The duration of a procedure is always an important variable that is taken into account. The shorter a procedure takes (while maintaining high-quality care), the more cost-efficient care you provide. Additionally, it is beneficial for the surgeons if the operation can be executed efficiently since performance pressure reduces. This often results in better well-being for the healthcare team, which is relevant because of massive burnout rates present in healthcare workers (Shanafelt et al. 2019).

All these complications affect certain actions within the medical procedure. As Mewes et al. (2017) describes it in one paper: “because of the special working conditions in the operation room (OR) and interventional radiology suite, i.e., sterility, limited space and time pressure, physicians face challenging human-computer interaction tasks.”. These human-computer interaction tasks vary from positioning the C-arm correctly, changing the layout of the image-guiding screen, guiding a specific artery stent, initiate a pressure analysis, recording images, monitoring the patient, the input of text, etcetera.

Figure 2.5 - The IGT OR in real life is messy and hectic

When looking at the complications mentioned before, there are primarily underlying touchpoints related to limitations originating from sterility. As O’Hara (2014) states in one paper, “At the heart of the constraints is the need to maintain a strict boundary between what is sterile and what is not.”. Wollgast et al. (2019) argues that currently used input methods “tend to interrupt workflows, decrease efficiency, increase the need for disinfection, and produce inaccuracy (Wollgast, 2017).”. These challenges can be seen as limitations of the workflow of many different processes. Hübler et al. (2014) states in one of his papers: “The quality of human-computer interaction influences the workflow of many interventions. While some groups propose systems that require a minimal amount of interaction (Meyer et al. 2007), other groups propose interaction devices and user interfaces that are specially designed for intraoperative use (Soehngen et al. 2012). In particular, interaction via gestures and voice represents a promising method for human-computer interaction within sterile environments (O’Hara et al. 2014).” In addition, Mewes et al. (2017) also touches upon eye-tracking or eye-gaze since all of these technologies present new ways of interaction with medical software under sterile conditions. These technologies have the potential of removing barriers in current medical contexts. Touchless interaction technologies enable potential speed-ups for specific tasks during current surgical procedures(Cronin & Doherty, 2019). Additionally, it allows for new interaction modes previously unavailable (Cronin & Doherty, 2019). This way, more control can be given to the operation’s interventional lead, resulting in less error-prone and indirect interactions. Therefore, this research’s relevance lies in mapping valuable use-cases where touchless interactions actually minimize barriers that the surgical team faces during a specific procedure in IGT.

Touchless interaction innovations

A brief overview is given per technology to get a feel for these technologies and their potential opportunities. This overview touches upon a short description of the technology, potential benefits, limitations, usability and reliability (since these are the most considerable non-functional requirements to overcome to achieve acceptance (Cronin & Doherty, 2019)), review and evaluation, resources, stakeholders and currently existing technologies. To create an idea of used touchless interaction methods, an overview is made, see figure 2.6.

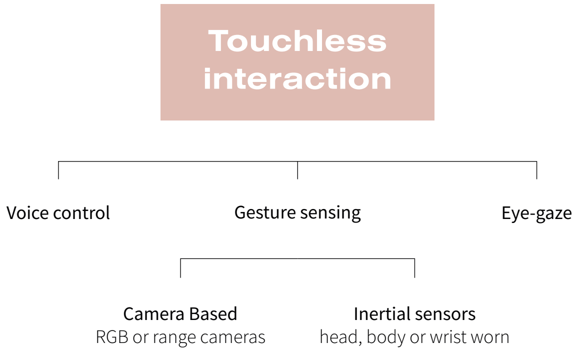


Figure 2.6 - Overview of touchless interaction technologies

General insights of touchless UI

Several aspects have to be taken into account regarding the consideration of implementing touchless user interfaces in a medical context. These findings originate from the literature that has been researched in this review.

- The stability and robustness of these interaction systems are also an important topic. “These systems should focus on being stable and providing basic access rather than trying to be more powerful and versatile” (Strickland et al. 2013).
- Training and calibration is an essential topic for all touchless interaction technologies. As Chao et al. (2014) states in a paper: “prior use of a device had a significant impact on task completion time”. The calibration process depends on the system that is being used but can result in a time cost. However, some systems require minimal to no preparatory calibration time.
- An important guideline for the usability of touchless UI technologies is the low cognitive load. This can be achieved with short, simple and natural interactions for voice control and gesture sensing (Wachs et al. 2011).
- It is important to consider comfort and fatigue to prevent physical issues for the doctors. This relates to the space the doctor has available for interactions and the space needed for specific interactions. Additionally, it should be considered that this interaction space should be defined appropriately to be noticed by the system (Cronin & Doherty, 2019).

These general insights give an idea of the initial qualities that must be considered when implementing touchless UI in a medical context. Analysing the touchless interaction technologies (voice control, gesture sensing and eye-gaze tracking) allows for a deeper understanding of related properties, considerations and requirements. To give a concluding, holistic overview of these technologies, a SWOT analysis is done. Mapping the strengths, weaknesses, opportunities, and threads enables the reader to understand the qualities of these technologies through an insightful schematic overview.

Voice control

“Speech technology has unprecedented opportunities for the health domain and these potential opportunities can be reaped to fix the current healthcare system.” - (Latif et al. 2021).

Nowadays, interest in speech-oriented technology is growing, leading to more and more research into the topic of using speech technology for interaction. In general, speech is the most natural mode of human communication. Latif et al. (2021) state that “it provides information about linguistic content and para-linguistic states and traits”. Linguistic content contains information about the message that is transmitted. Para-linguistic range, however, includes information on the speaker itself (identity, gender, emotion and age). In emerging voice control applications, recording with AI techniques like deep learning algorithms are increasingly significant to provide appropriate interaction possibilities. Therefore, insights of earlier research into this UI technology are collected from literature and earlier studies within Philips.

Findings from literature

When looking at the literature, it can be concluded that much research addresses the high potential this touchless interaction technology has in medical environments similar to IGT. The promising results of many different case studies show an improvement in efficiency and usability for specific actions within processes in healthcare.
The main opportunities that are addressed in the literature are based on automatic speech recognition with deep learning algorithms for processing. A medical voice assistant who gives intraoperative feedback for guidance during medical procedures is frequently mentioned (Latif et al. 2021). Other functionalities are verbal reminders or doctors’ notes in audio (Latif et al. 2021). Furthermore, it can be of high value for remote monitoring of patients and clinical documentation for doctors. “With 50% of a healthcare professional’s time is spent on clinical documentation, overwhelmed clinicians often spend more time on clinical documentation compared to direct patient care (Wallace, 2018) — a fact that can drain and demotivate clinicians.” (Latif et al. 2021). All in all, a broad domain of opportunities is mentioned in the considered papers.

However, many challenges are given as well. The most relevant barriers for the IGT context are people’s accents (Jacob et al. 2013) and ambient noise in the operation room, “with the noise levels of an OR making voice control extremely difficult” (Wachs et al. 2008). Additionally, scarcity of speech data, privacy-related issues and challenges regarding interoperability of isolated medical documentation between departments within hospitals are given (Latif et al. 2017). Nevertheless, with future considerations, it is expected that most barriers can be resolved. For which 5G connectivity and Internet-of-Things (IoT) based solutions are examples that show rapid development (Latif et al. 2021).

Findings from Philips

From earlier studies within Philips, several qualities and guidelines of these technologies can be found. Insights that are presented in these documents contain information about the technology’s ease of use and training. Since people are already familiar with using it in everyday life, there is a lower threshold for implementing it. The company ascertains a fast development and high potential for personal health assistants. “Combined with artificial intelligence, integration with data and existing business services, Conversational UI can grow into digital assistants that act in your interest or on your behalf” (Philips Conversational UI, 2017).

An important guideline that needs to be taken into account is the richness of the output media. The more human it is, the more likely users will emotionally resonate with the system (Philips Conversational UI, 2017). However, addressed issues around the need for feedback and limitations of conversational rules causes barriers.

Gesture sensing

“Gestures are useful for computer interaction since they are the most primary and expressive form of human communication (Wachs et al. 2011).” - (Schröder et al. 2014; Cronin & Doherty, 2019).

Gesture sensing is also an increasingly popular technology to implement into products. By providing seamless and natural control without physically touching a product or system, users in healthcare can maintain sterility, speed up processes or interact with systems while hands-busy (Cronin & Doherty, 2019). Sometimes it is even possible to interact with a system from a longer distance. Often these movement-based interactions are recorded via cameras or inertial sensors. Several studies claim that it has potential value for specific use-cases in human-computer interaction systems in medical contexts (O’Hara et al. 2014; Cronin & Doherty, 2019; Mewes et al. 2016). Therefore, insights of earlier research into this UI technology are collected from literature and earlier studies within Philips.

Findings from literature

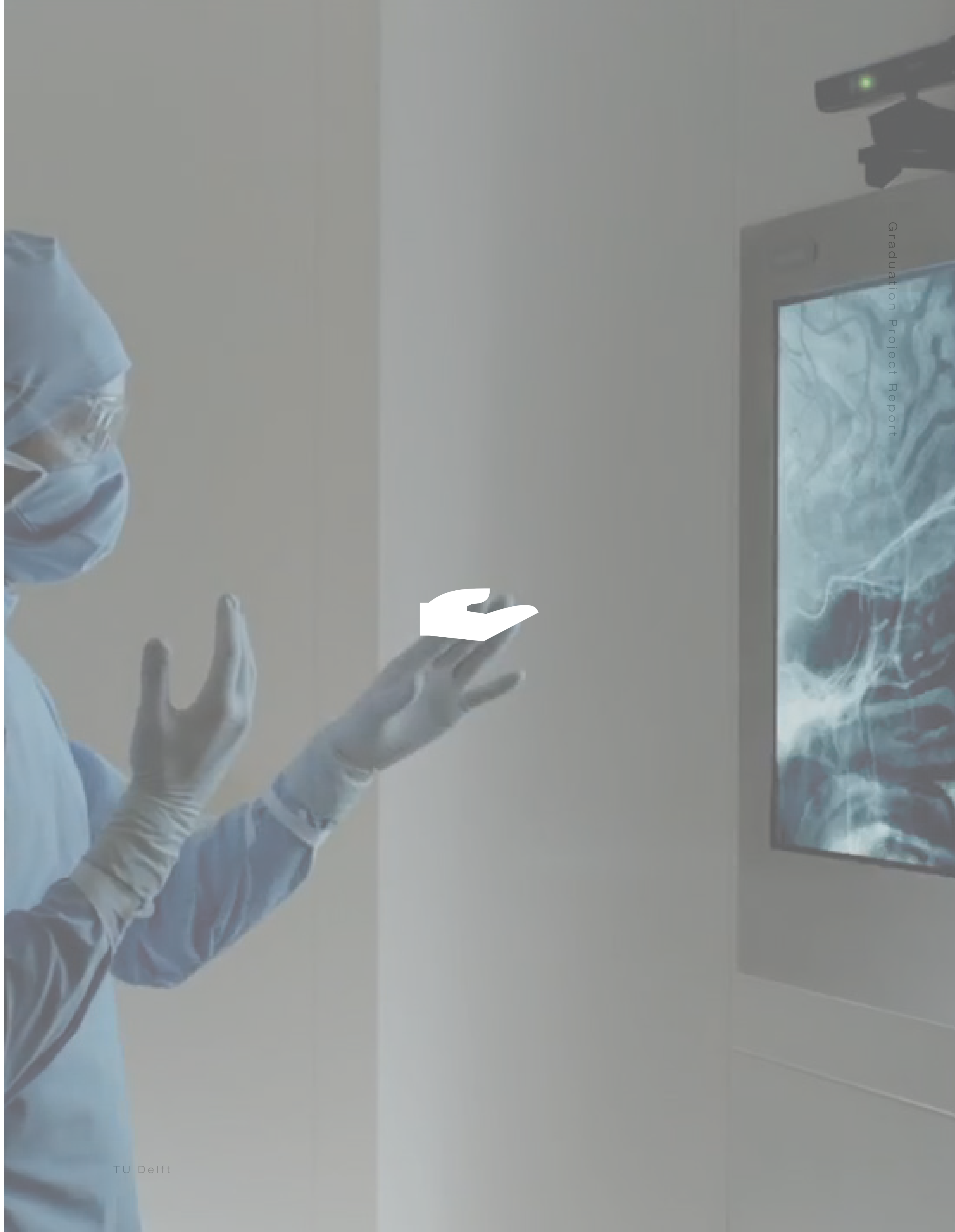
When looking at the literature related to gesture sensing technology in healthcare, it can be concluded that it has already been thoroughly researched. Therefore, a lot of different usability cases and prototyping has led to exciting opportunities for this technology.

Most of the opportunities in the literature are about maintaining sterility while navigating through and selecting medical images (Cronin & Doherty, 2019). Both coarse-grained gestures and finer spatial granularity of hand and finger gestures come into play (Johnson et al. 2011). Additionally, surgical pointers (Trejos et al. 2015), controlling an operation room table (Schröder et al. 2014) and on-screen layout adjustments (Johnson et al. 2011) are considered opportunities.

The challenges that are mentioned are primarily about training to adopt the interaction language. Related issues within this interaction language are unintended gestures and clutching. However, this could be solved with locking and unlocking functionalities (O’Hara et al. 2014). Additionally, it is recognized that physical space and flexibility is necessary to perform good interactions (Cronin & Doherty, 2019). For future considerations, foot and facial gestures provide solutions to interact within smaller areas. Also, body posture, shoulder movements and head movements are considered useful in the future.

Findings from Philips

Within studies that Philips has done over the years, several significant findings can be seen within the potential for implementing gesture sensing in medical contexts. The interactions with gestures can be executed in a very natural and seamless interaction language, resulting in a superior end-user experience (Philips Gesture Control, N.D.). The technique has mainly been tested on image manipulation within similar medical environments to IGT. However, these interactions often rely on a relatively high cognitive load that is very context-dependent. Therefore, it is not easy to generalize this gesture language to other application areas. “When designing for gesture control, a narrow focus on the user and product functionality can be risky. In real life, the user and product do not operate in isolation but are embedded in the context of use. The environment, workflow and socio-cultural setting all have a strong impact on whether gesture control can offer a true benefit and really ‘works’” (Philips Gesture Control, N.D.). Furthermore, it should be taken into account that a gesture should feel instantaneous and fluid while being possible to get it right every time (even without guidance) (Philips Gesture Control, N.D.).



Eye-gaze tracking

"Nine papers discussed the use of Eye-gaze technology as an interaction modality. Modern eye trackers have the advantage of being very easy to install and to use (Faro et al. 2010)." - (Cronin & Doherty, 2019).

Eye-gaze tracking is another technology that is an increasingly often implemented technology in a lot of different applications. The idea behind eye-gaze tracking is that you interact with systems through the movement of your eyes. Often this fine movement is recorded and measured with a camera(s).
Therefore, insights of earlier research into this UI technology are collected from literature and earlier studies within Philips.

Findings from literature

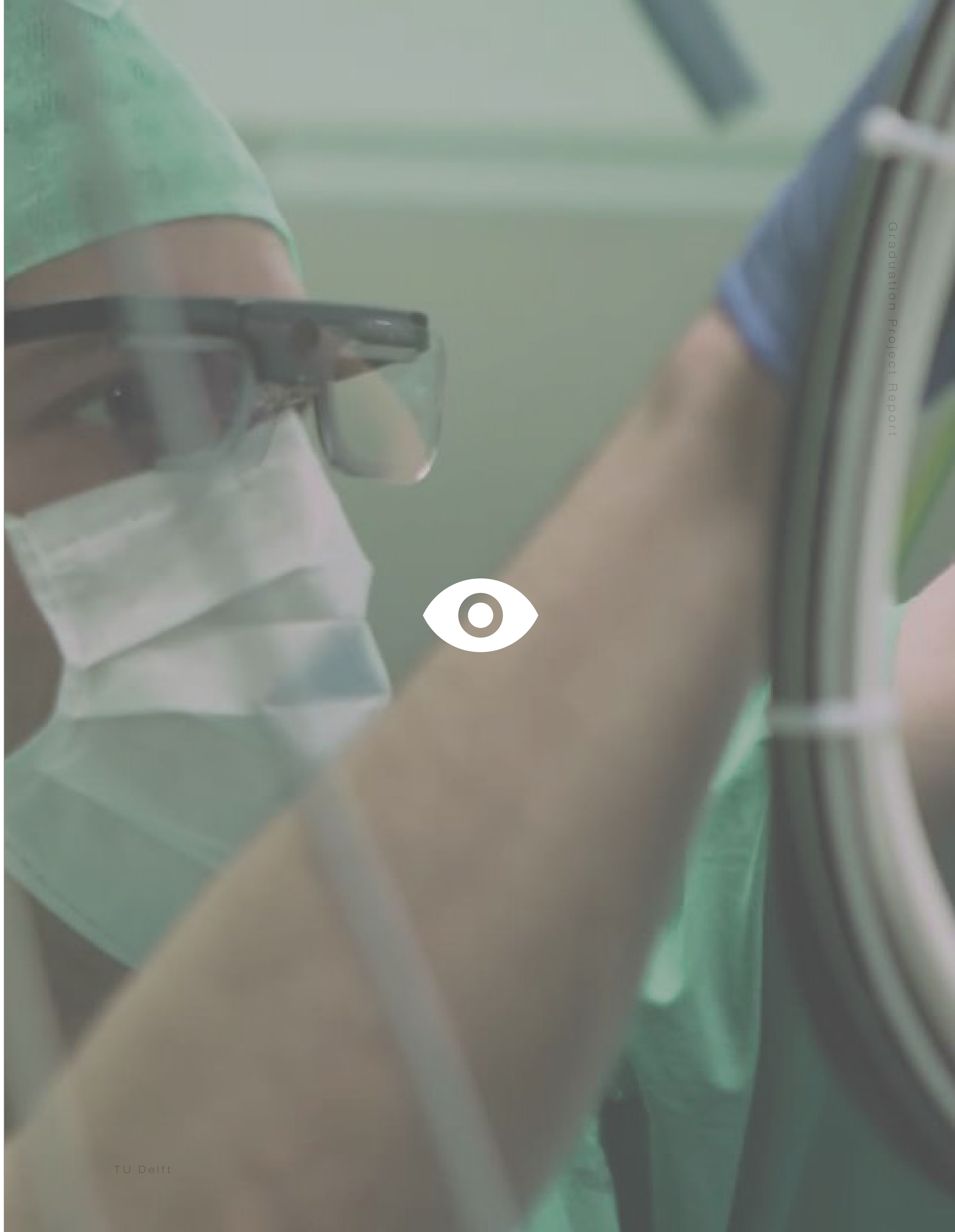
Reviewing literature regarding eye-gaze tracking technologies in healthcare, it can be concluded that relatively less research can be found. Nevertheless, it is interesting how potential opportunities are still valued very much.

The opportunities mentioned in the literature are about eye-gaze tracking as an additive technology that could have supportive or confirmative interaction functionalities to provide a more seamless touchless interaction (David-John et al. 2021). An example is given by Meng et al. (2016) in a paper: "If the user needs to interact with multiple applications on different displays, new gaze tracking approaches can help switch between them". Other opportunities are about accurate indication through an accurate pointer or on-screen autofocus. Furthermore, some 'passive' interaction opportunities like logging in and training procedures are given. The low cognitive load related to the usability of this interaction technology allows for a low threshold to implement it.

However, some barriers need to be taken into account. Using your eyes as output can feel unnatural for the user depending on the interaction that is executed. Additionally, within a multi-user environment, it can be complex to integrate and align these systems to prevent interference, drift and noise (Bigdelou et al. 2012). Nevertheless, considering the fast development of accuracy, reliability and usability, it is expected that these barriers will be entirely resolved in the near future.

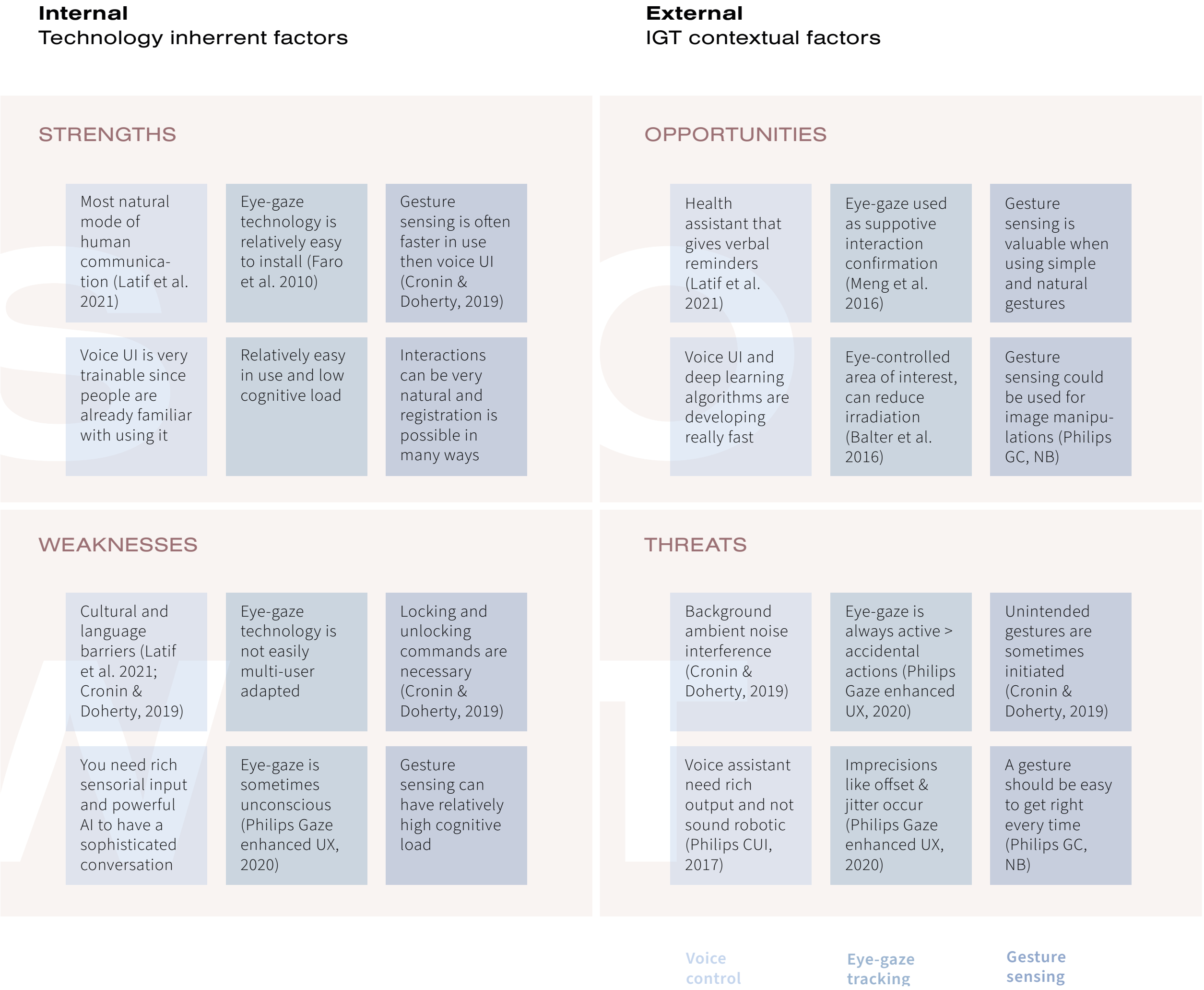
Findings from Philips

Earlier projects around eye-gaze tracking within Philips show interesting outcomes that should be taken into account before implementation. Other than the ease of implementation, ease of use and low cognitive load, eye-gaze technology allows for a certain degree of freedom (Philips gaze enhanced UX, 2020). Application areas where this technology shows high potential are in training, passively for evaluation and actively for guidance (during example, image interpretation) (Philips gaze enhanced UX, 2020). It can allow for better communication for remote interaction through eye contact and even reduce irradiation during procedures through indication support (Balter et al. 2016). Philips describes visual attention as an essential benefit because "this can help in various application areas ranging from more effectively evaluating different designs to aiding in smarter user interfaces and enhanced social cues for remote communication" (Philips gaze enhanced UX, 2020). But since the control of eye-gaze tracking is somewhat unconscious, unnatural as input modality, and eye-gaze sensors are always on, it can lead to accidental actions (Philips gaze enhanced UX, 2020). However, these imperfections and jitter and offset can be minimized with better hardware and innovative UI's.



SWOT analysis

To give an initial overview of all important insights gained from research into these technologies, a SWOT analysis is shown in figure 2.7. The strengths, weaknesses, opportunities and threats of all Touchless UI technologies are mapped in the schematic overview below. These are the essential insights, however, for the complete SWOT analysis, see Appendix A.



Internal
Technology inherrent factors

External
IGT contextual factors

STRENGTHS

Voice control	Eye-gaze tracking	Gesture sensing
Most natural mode of human communication (Latif et al. 2021)	Eye-gaze technology is relatively easy to install (Faro et al. 2010)	Gesture sensing is often faster in use then voice UI (Cronin & Doherty, 2019)
Voice UI is very trainable since people are already familiar with using it	Relatively easy in use and low cognitive load	Interactions can be very natural and registration is possible in many ways

OPPORTUNITIES

Voice control	Eye-gaze tracking	Gesture sensing
Health assistant that gives verbal reminders (Latif et al. 2021)	Eye-gaze used as suppotive interaction confirmation (Meng et al. 2016)	Gesture sensing is valuable when using simple and natural gestures
Voice UI and deep learning algorithms are developing really fast	Eye-controlled area of interest, can reduce irradiation (Balter et al. 2016)	Gesture sensing could be used for image manipulations (Philips GC, NB)

WEAKNESSES

Voice control	Eye-gaze tracking	Gesture sensing
Cultural and language barriers (Latif et al. 2021; Cronin & Doherty, 2019)	Eye-gaze technology is not easily multi-user adapted	Locking and unlocking commands are necessary (Cronin & Doherty, 2019)
You need rich sensorial input and powerful AI to have a sophisticated conversation	Eye-gaze is sometimes unconscious (Philips Gaze enhanced UX, 2020)	Gesture sensing can have relatively high cognitive load

THREATS

Voice control	Eye-gaze tracking	Gesture sensing
Background ambient noise interference (Cronin & Doherty, 2019)	Eye-gaze is always active > accidental actions (Philips Gaze enhanced UX, 2020)	Unintended gestures are sometimes initiated (Cronin & Doherty, 2019)
Voice assistant need rich output and not sound robotic (Philips CUI, 2017)	Imprecisions like offset & jitter occur (Philips Gaze enhanced UX, 2020)	A gesture should be easy to get right every time (Philips GC, NB)

Figure 2.7 - Most important insights from SWOT analysis of all touchless UI technologies considered

Literature synthesis

The barriers originating from interacting with the interventional systems are sometimes not acknowledged by the clinical users themselves. A study by Hübler et al. (2014) revealed several problems during the workflow of 25 interventional neurology procedures: (1) Clinicians have to leave the sterile area to retrieve additional patient data in the control room. (2) Clinicians trying to perform an interaction with the system while it was busy. (3) Clinicians trying to interact with an interaction element that is out of reach or blocked by another user. When discussing these problems with the clinician, they addressed that they already recognized these observed problems. However, “surprisingly they did not describe them as very distracting. Instead, they explained that they got used to these problems and considered them as a part of their daily work.” (Hübler et al. 2014). Other studies address issues in the OR from interaction problems between users and the system (Benzko et al. 2016). Fairbanks and Caplan (2004) point out that “many errors are caused by incorrect expectations, and a poorly designed human-machine interface being the main cause of many medical errors”. This is backed up by multiple academic studies that emphasize the importance of reliable and user-centred human-computer interaction to avoid significant amounts of errors (Osvalder and bligard, 2007; Backhaus, 2010; Hölscher and Heidecke, 2012). Wong et al. (2009) quantifies the most frequently occurring inefficiencies originating from device error (29%) and communication error (27%). This is approved in a study by Lingard et al. (2004) in which it is introduced that disruptions in communication in the OR are a significant source of errors. The reasons for these errors are “increasing cognitive load, interrupted routines and increased tenseness between surgical staff “ (Lingard et al. 2004). In an observational study, correlations are found between interruptions and miscommunication during surgery and time spend on that procedure (Gillespie, Chaboyer and Fairweather, 2012).

Dealing with these inefficiencies often leads to working around the problem, repetition or interruptions and miscommunications. These occurrences can be very time-consuming, resulting in less efficiency and higher costs. Therefore, it would be valuable if these occurrences could be minimized.

Some studies show a significant potential decrease in errors and time spend on specific actions. From these, specific intraoperative studies have selected that scope their considered interactions to being executed with new UI designs or touchless interaction innovations. One study by Fotouhi et al. (2020) that uses touchless UI through spatiotemporal-aware AR to redefine human-computer interaction in IGT presents significant improvements in time, number of X-ray acquisitions, radiation dose, and clinical outcomes. By executing two intraoperative actions with their spatiotemporal-aware AR setup and comparing it to standard procedure times, an increase in speed can be acquired for ‘k-wire insertion’ that is five times as fast, and for ‘acetabular implant placement’ that it is two times as fast. Some other bottlenecks like usability and communication can be minimized with touchless UI technologies. Sometimes touchless UI could provide solutions for which clinicians do not have to leave their direct sterile environment. This allows for more efficient and usable system interaction. An earlier study from Philips (2017c) shows that “87% of the users believe that the possibility to access and control more applications at the patient tableside, will lead to fewer miscommunications”.

Therefore, these innovative technologies are relevant and suitable for application within the context of IGT to improve efficiency and minimize bottlenecks.

02 – 3 **Opportunity definition**

Since the Quadruple Aim represents a good foundation of healthcare innovation, it is a valuable framework to take into account. Considering the Quadruple Aim, the performance of medical procedures can be an essential topic to focus on. When the workflow within medical procedures is optimized, more efficient care can be delivered. From the literature review, it can be concluded that this results in fewer costs, improved patient experience, more attention given towards the quality of care, and improved medical staff experience.

Very strict (hygiene) constraints limit the performance of the healthcare staff in these medical environments. Therefore, a lot can be improved on the procedures that the healthcare staff execute, with a future perspective, where healthcare organizations are obliged to keep innovating to be able to develop their delivered care. Combined with the inclusion of the Quadruple Aim, Philips has an opportunity to drive this innovation and provide solutions that allow for the optimization of workflow.

Based on these insights, the following **research question (RQ)** will be answered in this graduation project:

> *"How can the healthcare staff be supported with touchless interaction solutions, during PCI procedures in IGT, to improve workflow?"*

Improving workflow as a critical objective focuses on simplifying interactions, minimizing necessary interactions or shortening interactions. To give more structure to this research, the research question could be divided into several sub-questions (SQ). This helps to structure the overarching research goal into several specific subjects.

SQ - 01
How can the workflow of the healthcare staff be improved for PCI procedures?

SQ - 02
How can touchless UI solutions optimally be combined and applied to provide solutions?

SQ - 03
How can the healthcare staff be supported in their interactions?

SQ - 04
How can these design solutions, based on PCI procedures, be translated towards every medical suite in IGT?

SQ - 05
How are barriers minimized for doctors in the cath lab, to use and adopt these technologies?

The design goal of this opportunity is to have a strategic roadmap that can deliver concrete insights and provide guidance in the implementation possibilities of these touchless UI innovations in this healthcare domain.
It will touch upon system and workflow integration, proposed concepts, service propositions, potential barriers, etcetera.

02

CHAPTER CONCLUSION

In conclusion, after introducing the complex medical environment, explorative literature research is done. This uncovered several bottlenecks in the context of IGT that lead to complex inefficiencies. Often these bottlenecks come down to major considerations, like sterility and hands-busy situations. However, touchless UI technologies provide solutions in many ways. Interactional properties are gathered from literature and previous studies from Philips. These take-aways will be considered in a later stage of this project, the design phase. Technologies like eye-gaze, voice control and gesture sensing are expected to minimize the number of mistakes made and time that is lost because of inefficiencies. Therefore, this design project is an exciting opportunity to solve the following research question.

“How can the healthcare staff be supported with touchless interaction solutions, during PCI surgery in IGT, to improve workflow?”

The design goal of this opportunity is to have a strategic roadmap that can deliver concrete insights and provide guidance in the implementation possibilities of these touchless UI innovations in this healthcare domain.

In the next phase, the context of IGT is explored. Looking at future trends and developments, a future vision is formulated that gives direction for the development of this context. Additionally, a design focus is established through exploring the current interactions in the context of IGT.

UNDERSTAND take-aways

- Understanding the context
- Recognition of previous research
- Obtaining take-aways for designing with these touchless interaction technologies
- Defining the design research project

03 EXPLORE

This chapter is about exploring the current and future context of IGT to define opportunities and anchor points for the design process. The future context of IGT is explored by doing creative trend research to get an idea of the technologies, trends, and developments in the future healthcare landscape. This overview is captured in a future vision that provides a direction of the future in which contextual boundaries and guidelines are considered. Since this graduation project has an interactional focus, the current interactions of IGT procedures are explored to find insights that lead to opportunities for improving these procedures. This exploration phase will be concluded with a design vision that contains a clear objective for the upcoming phases.

03 - 1 **Future of IGT**

In a constantly changing innovative sector like IGT, it is important to consider future needs and developments to strategically plan innovations. Because of the aim to stay relevant within this context, creative trend research and future visioning are insightful methods to get an idea of possible future directions in line with relevant developments, states, principles, and trends within a specific time frame. The creative trend research method "combines the designer's craft of intuitive observations with the strategic scanning of the environment" (Simonse, 2017). To capture these developments, a future vision is made. A future vision statement "provides a strategic reference point- a focused direction that leads to stronger motivation. These visions imagine experiences of future innovations" (Simonse, 2017).

To get a concrete idea of future developments and trends of IGT, a scope is applied for specific relevant subjects within this context. Some demographical/social trends are gathered to get an idea of the general human considerations. Additionally, healthcare trends are taken into account for researching the evolution of the market. Future technological outcomes are also considered to explore how these innovations could influence the healthcare sector. For an overview of the trend analysis, see Appendix B.

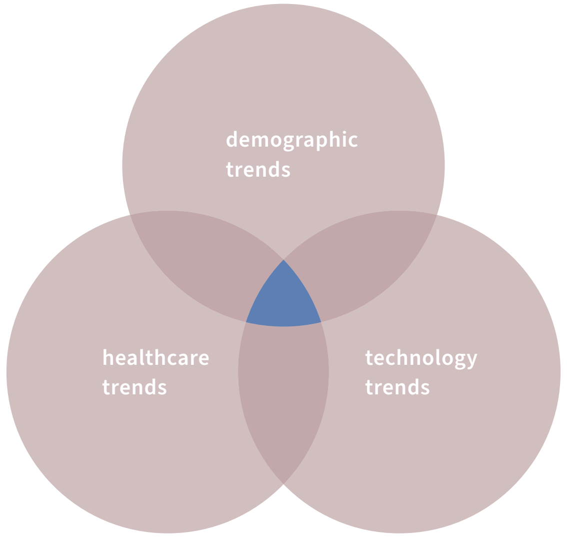


Figure 3.1 - Visual representation of future scope of trends and developments

Selection of trends

Demographic trends

The ageing population (World Health Organization, 2018) presents opportunities and challenges for businesses and institutions. It also leads to a growing segment of older employees in the workforce (PwC, 2021). However, it is essential to manage HR alignment carefully to make strategic and appropriate decisions in employing people. Because, nowadays many hospitals are struggling with a shortage of employees (Ligtvoet, 2019).

Healthcare trends

A new generation of healthcare professionals that are more digitally equipped and knowledgeable (Philips, 2020) will allow for a technology-assisted focus on agile and efficient healthcare (Greenspun, 2020). Due to the increased healthcare costs (Popken, 2020) and generally more people that need care with increasing complexity in patient pathologies (Smith et al. 2013), it is relevant for the healthcare sector to develop towards providing value-based care. Hence, improvements in staff and patient experience and health outcomes are necessary. This requires faster and smoother workflows (Philips, 2020).

Technology trends

Important and valuable technology-based innovations for hospitals are 5G connectivity (Philips, 2020) and Smart environments (Enisa, 2016). Applying these cloud service ecosystems will allow hospitals to create seamless care assets that can be used, e.g. remote care, interconnected clinical information systems, data analysis, and networked medical devices. With opportunities for wearable technology integrations (Healthie, 2021), AI as a smart assistant, and augmented reality (AR) (van Meurs, 2019), natural, seamless and personalized, touchless interactions can be facilitated to provide for improved workflows in IGT (Philips, 2020).

Future vision for IGT

"A future vision is an expression of a desired future where it provides a strategic reference point for actionable innovations." - (Simonse, 2017)

A future vision statement describes the end goal as an expression of the desired future on a roadmap. Therefore, it equips a leap towards a future context in which value wishes are captured. Beyond this desired future aim, a vision has four distinguished properties (Simonse, 2017):

- **Clarity** – the vision expression enables immediate understanding of what it would be like to experience the future innovation in the explicitly expressed desired end state.
- **Value** – drivers capture the compelling benefits of value wishes: wherein the specific value fulfils an unmet need or solves a dilemma of a user target group in the future.
- **Artefact** – materialise the imagined value wishes with images in 2D or 3D-dimensions.
- **Magnetism** – involves the desirability and attractiveness of the vision – 'the thing' the vision creators are truly passionate about in such a way that it potentially energizes others to direct their actions towards it.

My interpretation of the future

Since a new generation of healthcare professionals is on the rise, a specialized medical team familiar with more digital support is expected to execute these procedures. Additionally, the team members will be appropriately aligned and matched to enable efficient teamwork and communication. Digital familiarity is beneficial when increasingly significant technologies and smart systems, support and guide the interventional team during medical procedures. By facilitating touchless user interfaces, a natural and efficient workflow can be realised in which no limitations and inefficiencies are emerging because of sterility, communication problems and hands-busy situations. Support and guidance through Artificial Intelligence allows for these procedures to be personalized to both the experience of the medical team as well as the patient, delivering improved health outcomes and care that is directly adding value. Capturing these interpretations into one visual artefact results in the graphic below (see figure 3.2). The initial image for this artefact is a visually elaborated existing future vision of Philips – IGT. However, the basic principles of this direction align very well with my interpretation of the future.

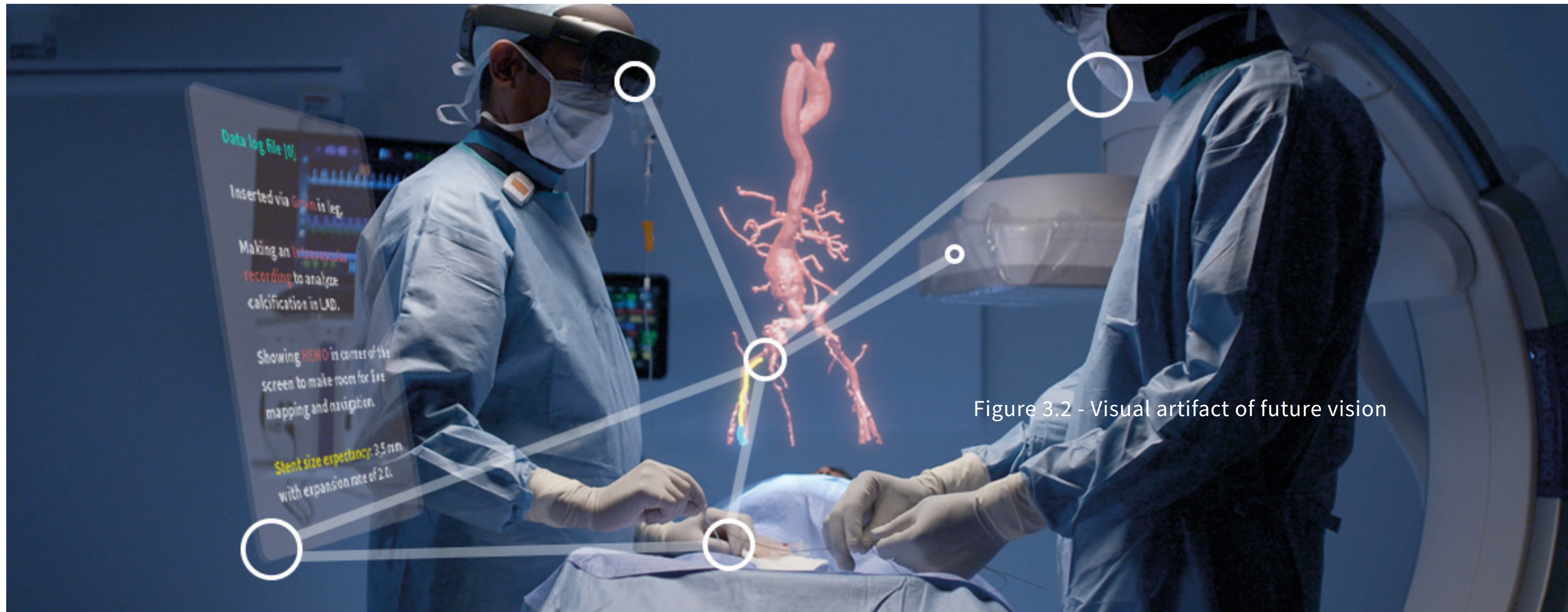
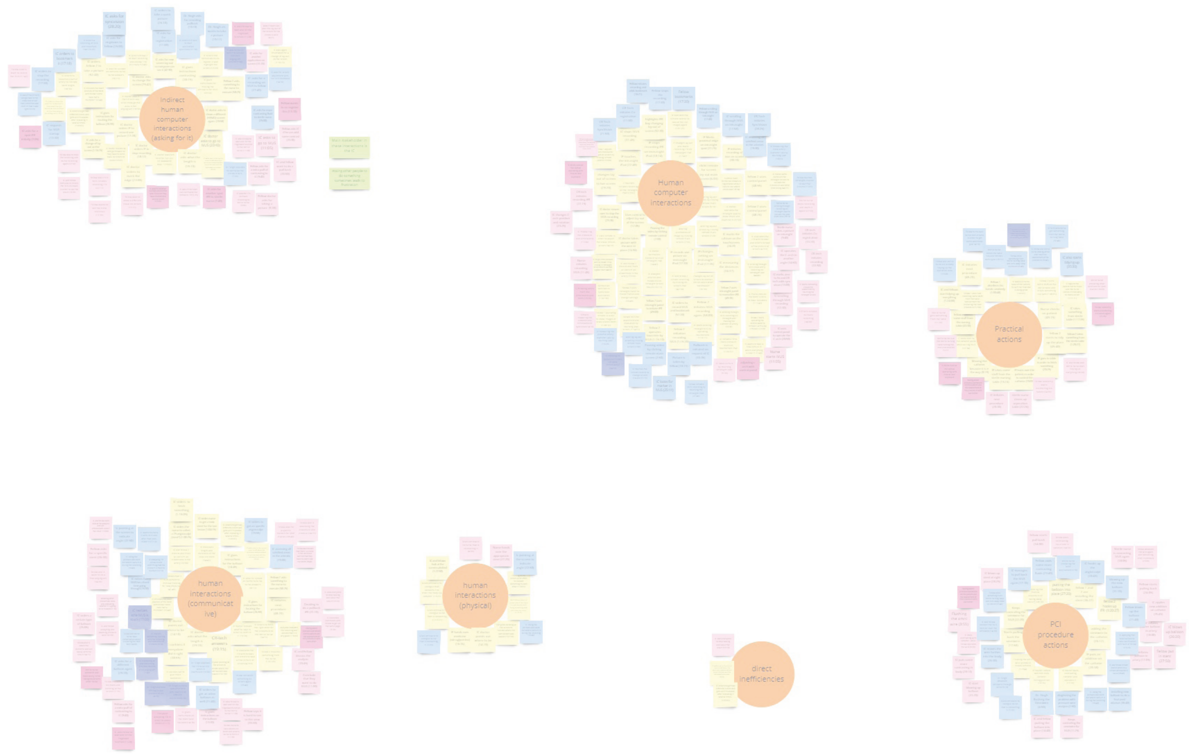
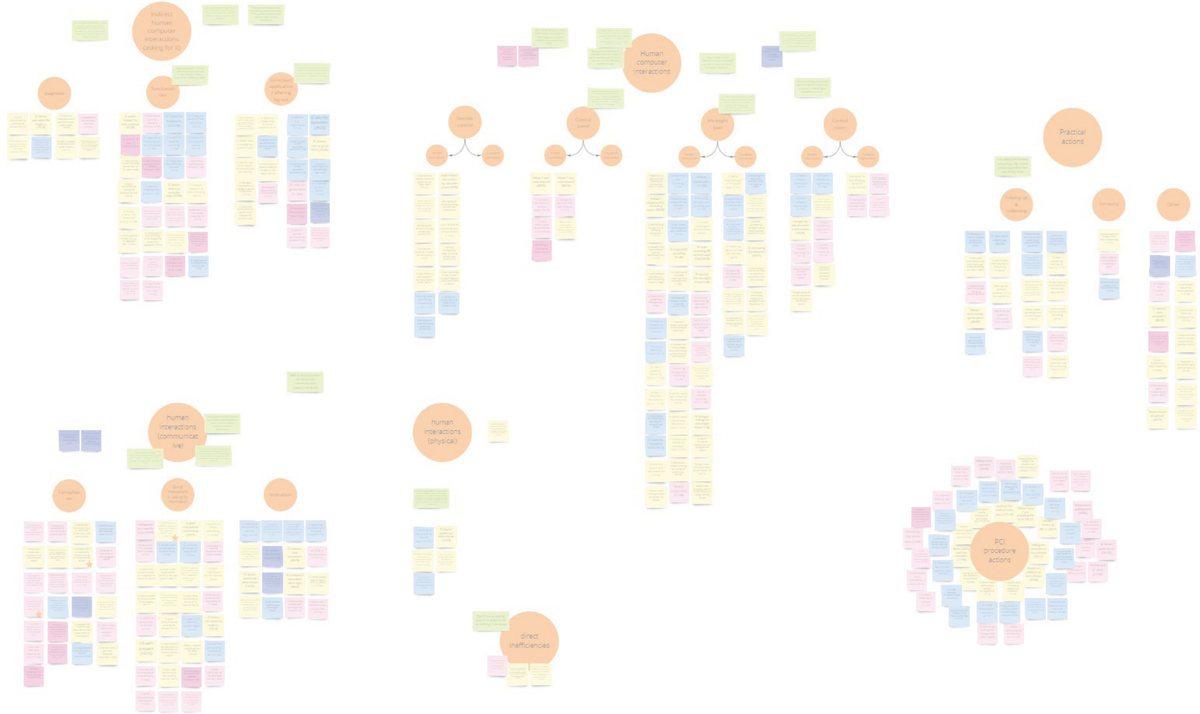


Figure 3.2 - Visual artifact of future vision

FUTURE VISION OF IGT

The role of IGT develops towards solving patient pathologies with both an **aligned medical team**, and **significant technological support of multiple smart systems**. An optimized, integrated and efficient workflow supported by **touchless interaction solutions** will contribute to **value-based care** provided within the context of IGT.





03 - 2 Exploring interactions

Since the focus of this project is based on interactions during medical procedures in IGT, an explorative analysis of all the current interactions happening during PCI procedures is done. A generally averaged idea of interactions can be derived by watching three video- and audio-recorded PCI procedures from within the last two years. Using the initial observation of the first procedure as a foundation, the other procedures are mapped similarly, addressing similarities and differences from the first observation. As a result, a holistic and substantiated analysis with different variables is conducted.

During the observatory study, several variables are taken into account and mapped with the coding of the procedure time. During the analysis, quotes are captured to give qualitative depth to certain situations. Sometimes a situation leads to an interesting case that is written down as initial insights on separate post-its. When it is crucial to extend situations with contextual circumstances, images are recorded and added to the timeline. Most importantly, all the interactions happening in the cath lab are written down on post-its (see Appendix C). These interactions vary from human-computer interactions (HCI) and human interactions (HI) to interactions related to the medical procedure. For all HCI, there is a distinction between direct HCI and indirect HCI. Direct interactions being first-hand interplay with a digital system, and indirect interactions including commands or requests from one stakeholder to the other to execute an action with a computer. Additionally, there is a difference in communicative HI (verbal) and physical HI (touch-based). These interactions form the foundation of a

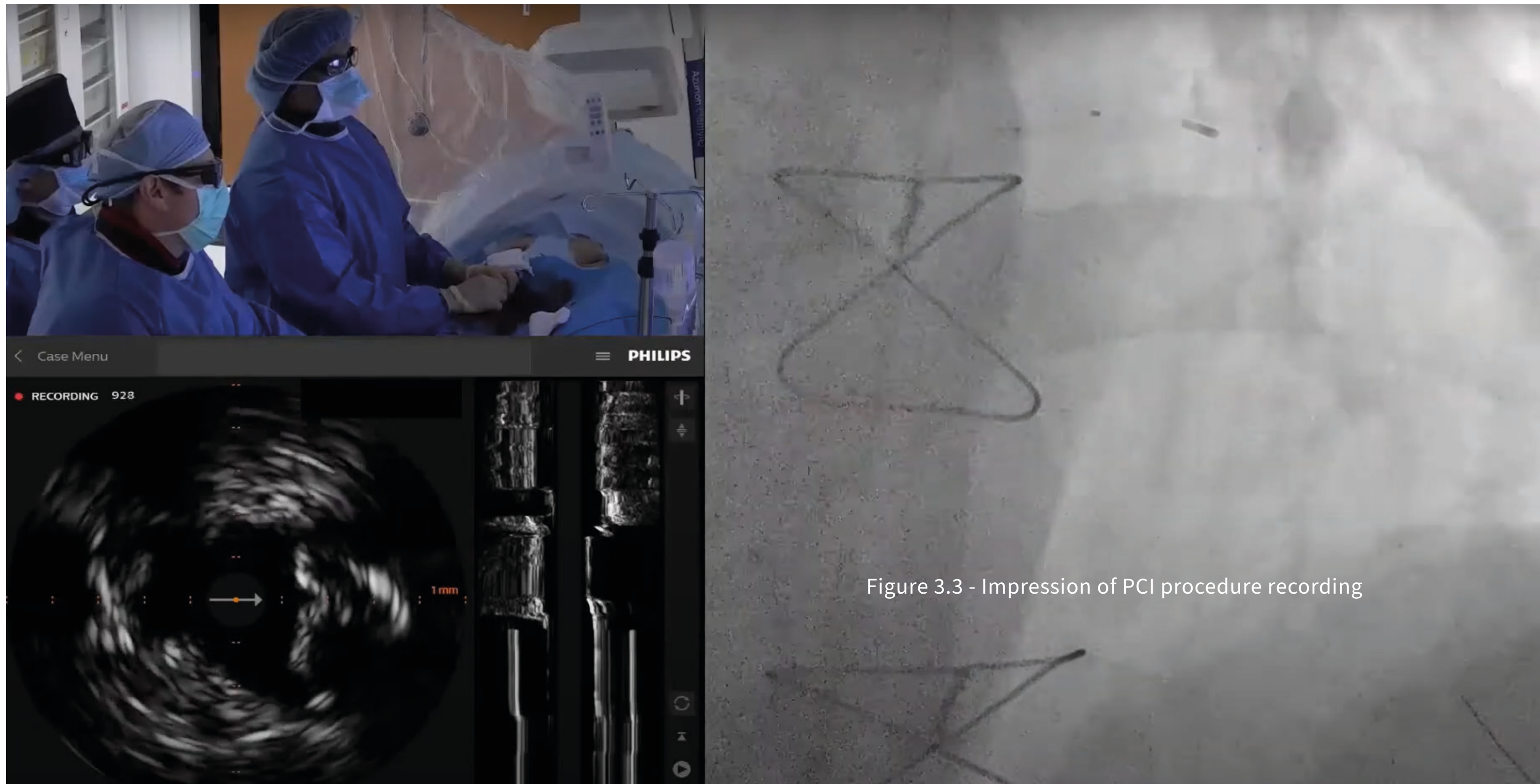
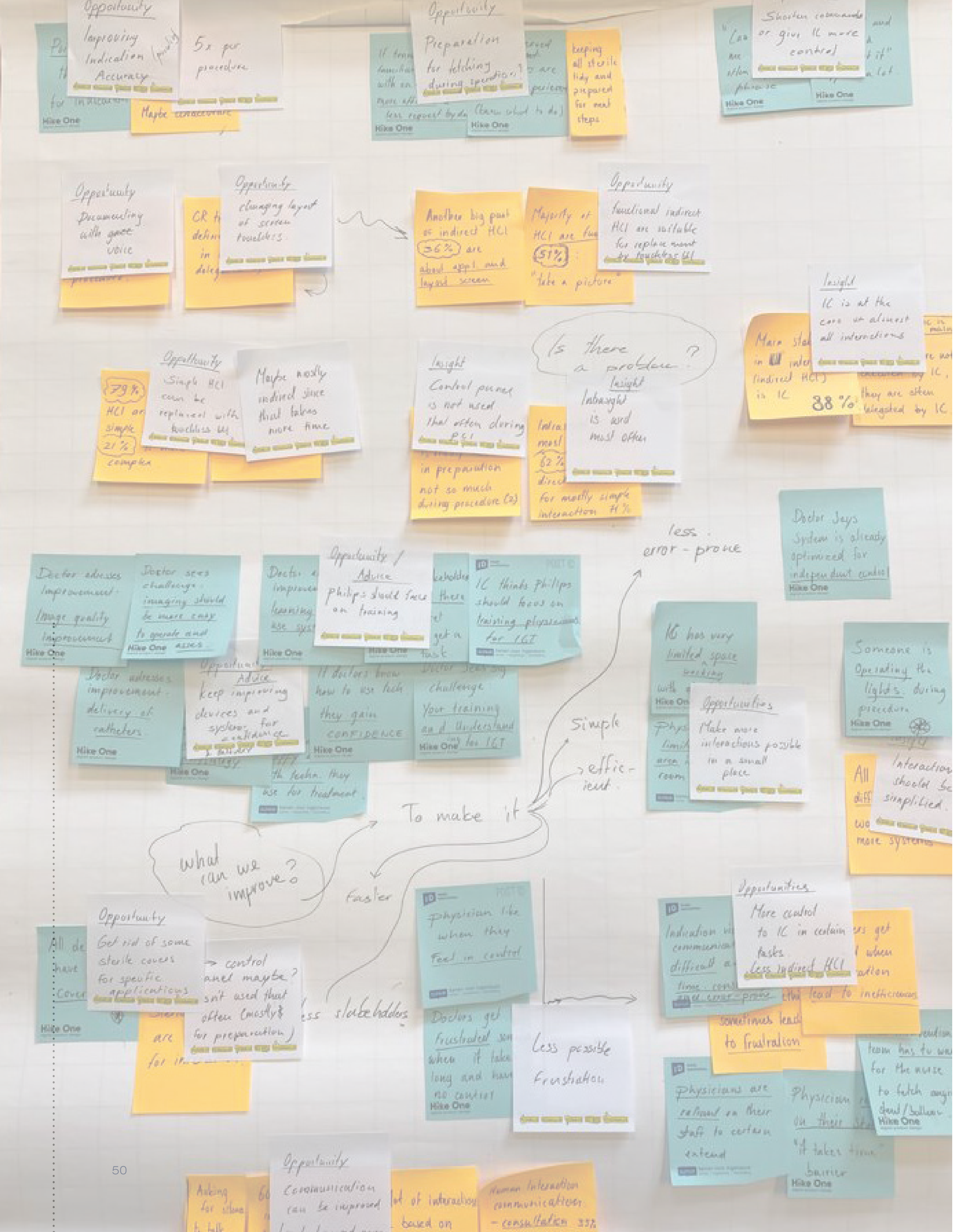


Figure 3.3 - Impression of PCI procedure recording



framework in which these considered interactions are mapped schematically (see figure 3.4). On the X-axis, a distinction between interaction originating from physical and communicative action is made. On the Y-axis, a distinction is made to separate interactions that directly contribute to the medical procedure (leading) and support the medical procedure (supporting). This creates a quadrant in which the earlier described interactions fit accordingly. The proportions and an example for every quadrant are given.

By making the subcategories of interactions, other insights can be derived. Several examples of these insights are:

- A significant part of the indirect HCI is about screen layout adjustments.
- 60% of all interactions are based on communication (indirect HCI and HI).
- Asking other people to do something sometimes leads to frustration because the doctors want to have control of themselves.
- The main stakeholder in the indirect HCI is the IC. From him, almost all interactions originate: 88% of all interactions.
- The interactions should be simplified and natural if they are changed.
- When devices and systems are improved, doctors gain confidence and are happy with the delivery.
- …

These separate insights result in constructed opportunity areas that are substantiated with original insights, quotes, images, initial ideas and potential value. These opportunity areas are discussed in the next chapter.

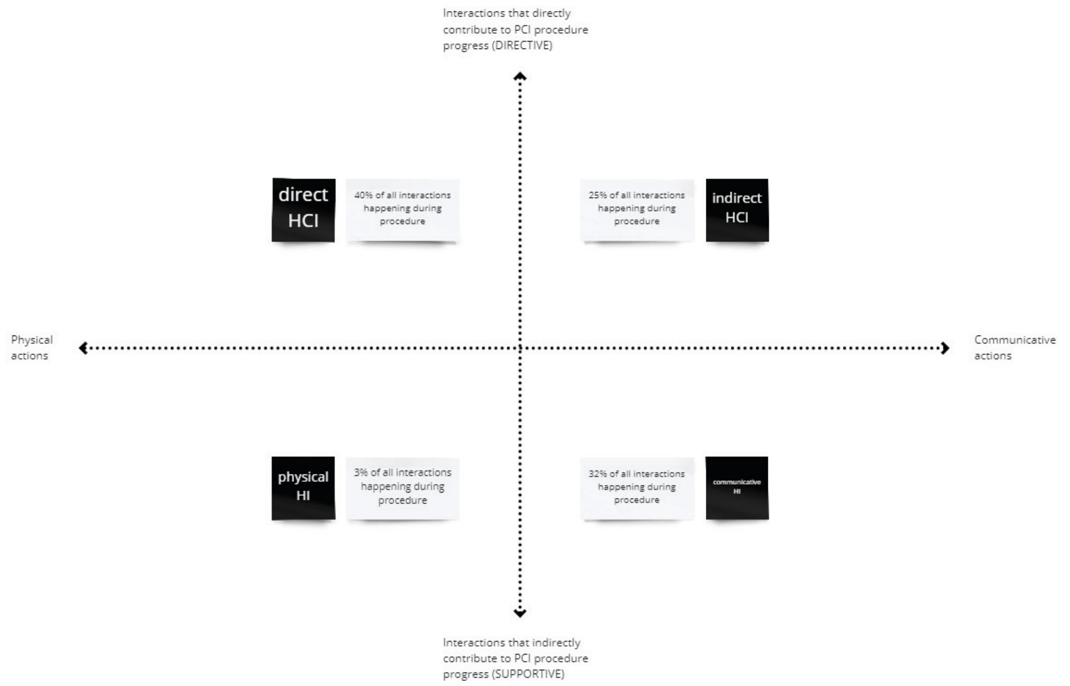


Figure 3.4 - Schematic framework of considered interactions

03 - 3 **Opportunity areas and focus**

As mentioned in the previous chapter, the gathered insights were clustered into opportunity areas. These opportunity areas were substantiated with a general description, a value proposition, some initial ideas, and quotes and insights from the analysis. Removing most of the overlap in the opportunity areas, seven final opportunity areas are derived from the analysis (see figure 3.5).

Opportunity areas

Every opportunity area is fully elaborated in presentation cards that can be found in Appendix D. However, to give an initial idea of the contextual opportunity, a brief description is given of every defined area.

Equip the doctor with more dierct interactional control
Requesting someone else to execute a task is often time-consuming, error-prone, and sometimes leads to frustration. When full control can be given to the doctor, this will lead to more efficiency and reliability.

More effective communication channels
60% of all interactions are based on communication. Taking into account all the complexity and chaos, it is crucial that communication is effective.

Improving communicative indication accuracy
Accuracy is lost when people have to point towards a screen to indicate something. Since efficient and precise communication is an essential element, this is considered an interesting opportunity area.

Improving interaction usability
The sterile wraps around the devices cause interaction styles that are not in line with how they were designed. Therefore, usability features are lost.

Improving training for physicians
Physicians gain confidence and happiness when they are in control of the systems and devices. It is crucial to train them accordingly when innovative technologies are implemented.

More efficient documentation means
Documenting is always a time-consuming task that is never ideal to execute at the end of the day. Therefore, with voice control during the procedures, time could be minimized.

Optimizing intraoperative collection of materials
During the procedures, the sterile medical team often has to wait for someone to collect the necessities. When an efficient workflow can be maintained without having these stalled moments, this is always desirable.

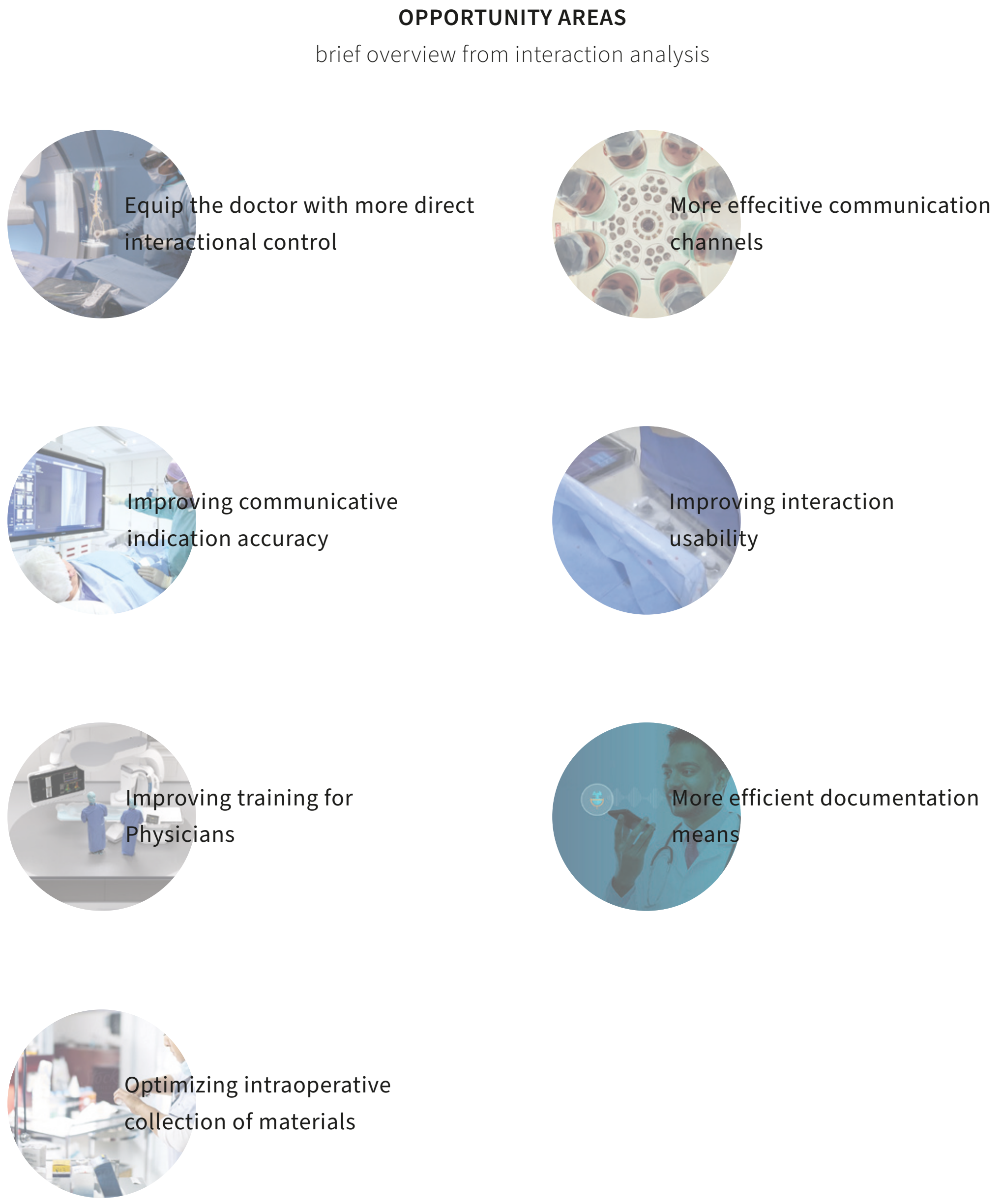


Figure 3.5 - Overview of resulting opportunity areas from the interaction analysis

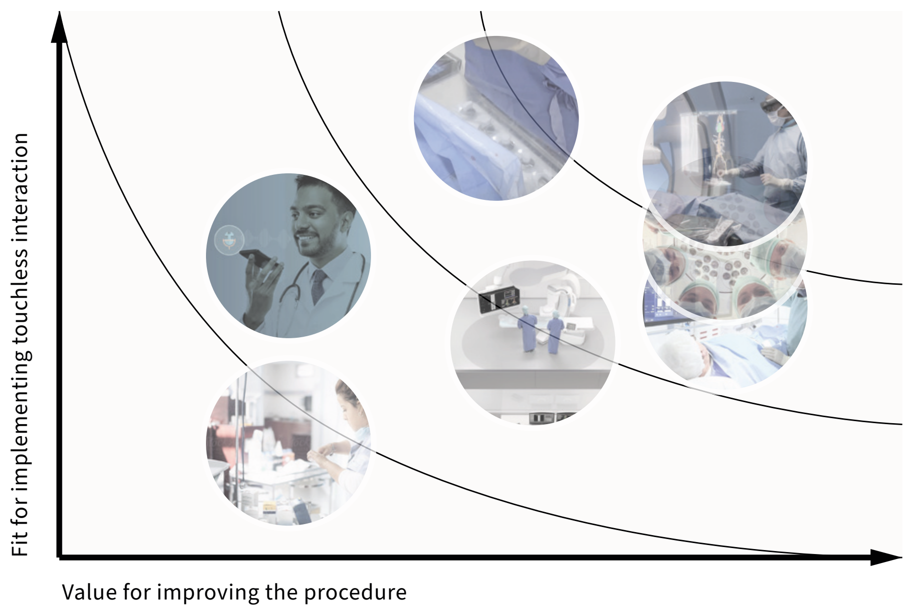


Figure 3.6 - Mapping of opportunity areas with innovation expert of IGT

Mapping opportunities

To assess the potential value of these areas, An innovation expert within the medical context of IGT (from Philips) is asked to map these separate elements in a schematic overview. On the X-axis, the potential value for improving the procedure is classified by discussing every topic. The fit for touchless UI technologies is evaluated on the Y-axis to assess whether these technologies are feasible, desired, and viable for a specific opportunity. This results in a value-mapping overview (Simonse, 2017), which can indicate the best design direction (see figure 3.6).

Chosen design focus

Since one specific opportunity area shows the highest potential and covers multiple problems in the context of IGT, it can be selected as a design focus: *Equip the doctor with more interactional control*. From the interaction analysis can also be concluded that improving this opportunity scope, will result in significant workflow improvements.

Looking back at the interactional framework presented in the previous chapter, a design focus can be highlighted of the significant part of indirect HCI (see figure 3.7). This results in the following design vision statement (see next page).

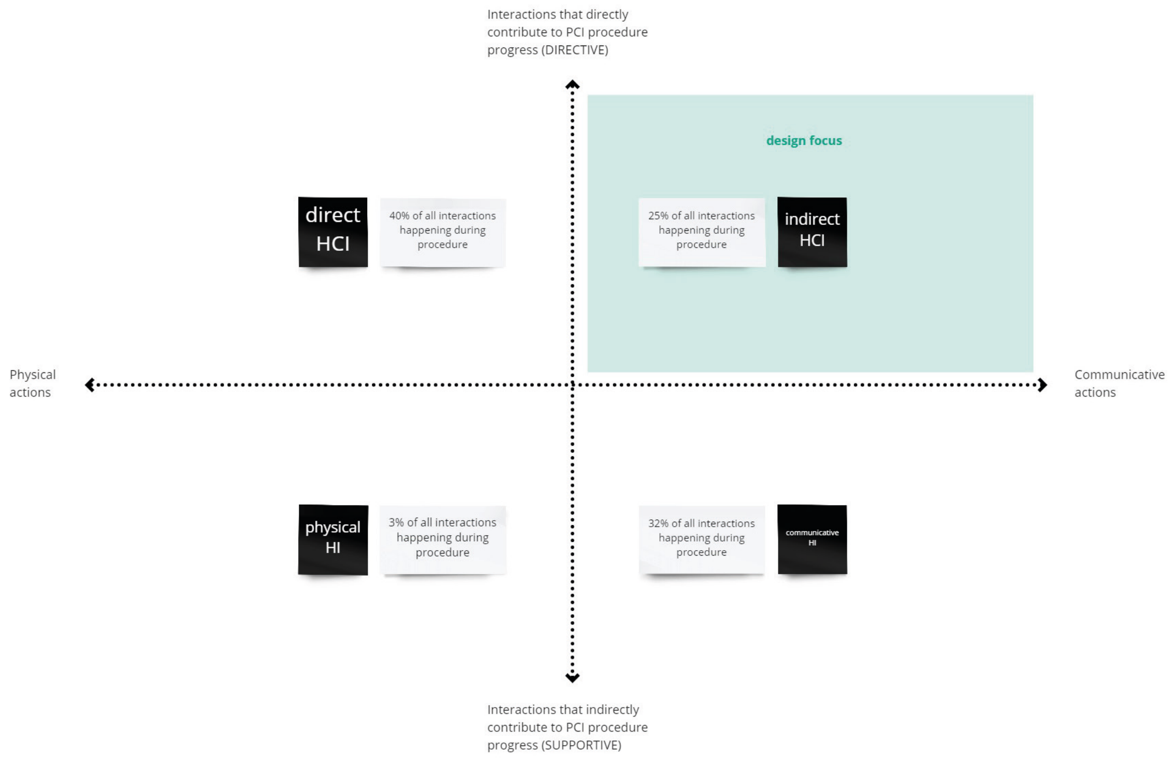


Figure 3.7 - Visual representation of the design focus in a framework

DESIGN VISION

I want to realise supportive interactions through **Touchless UI**, that give the IC **more control** to optimize **procedure workflow** in IGT, by taking away **all indirect HCI**.

03

CHAPTER CONCLUSION

In conclusion, this chapter explores IGT's current and future context and captures it in several statements: a future vision and a design vision. The future vision is based on the most important trends and developments that can be seen at the moment. This vision gives a clear direction that is used in a later stage of this project to align the design of the roadmap. The design vision gives a concrete scope for imagining and designing within certain boundaries. It is based on findings from an observational study executed to identify substantial bottlenecks and opportunities. Capturing these opportunities in presentation cards allowed for clear communication. When mapping these opportunity areas into a schematic overview, some overlap is identified between these opportunity areas. Scoping the most interesting and valuable opportunity area leads to a holistic and relevant design scope.

In the upcoming phase, insights and perspectives on this opportunity area are gathered. For that purpose, interviews are conducted to get a deep understanding of the values and expectations of the end-user from different perspectives.

EXPLORE take-aways

- Shaping the expected future context of IGT
- Diving into current interactions during procedures
- Defining opportunity areas for improvement with touchless UI
- Scoping the project with a design direction

04 IMAGINE

This chapter is about diving deeper into the design scope and empathising with the end-user to achieve a solid foundation for the design phase. Therefore, a research model is developed to validate the opportunities found in the exploring interaction analysis and prioritize value drivers for touchless interaction. The research model is based on a semi-structured interview combined with a workshop that is conducted with multiple stakeholders that are relevant in the context of IGT. The findings can be translated into design requirements, guidelines and challenges that provide a holistic overview of the user's needs and desires. In the end, the ideation and selection process are presented, providing insight into the imaginative brainstorming and collection of ideas.

04 - 1 Research method and template

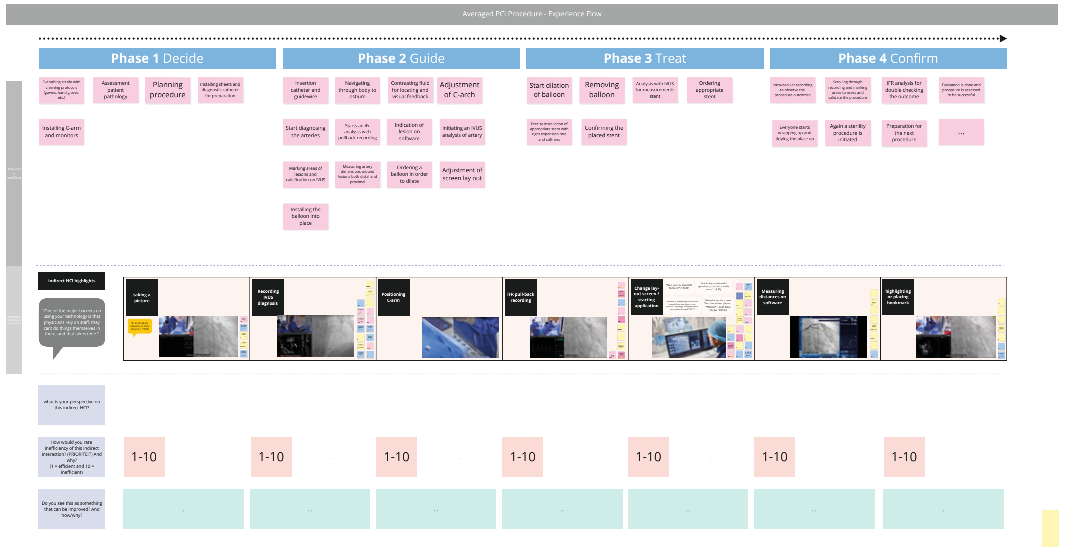
In order to gain insights and understanding of this design scope, it is important to gather more in-depth information from stakeholders related to IGT. By examining their perspectives on the main elements from the design vision, the scope can be validated and prioritized further. An overall understanding of what is important to different stakeholders of IGT is the main objective.

This research will be executed with a semi-structured interview combined with an online workshop (see Appendix F). The interview part will touch upon their own experiences in IGT, their perception of current developments and their vision towards the future of IGT. It also introduces touchless UI technologies and questions interviewees about their opinion towards applying these technologies in the future. Additionally, there is room for the interviewee to provide some input on recommendations and problems from their own experiences. The workshop will consist of two exercises that each have a different goal. The first exercise is about validating the design scope and rating specific situations that can be improved to indicate relevance (see figure 4.1). The other exercise prioritises value drivers for touchless interaction qualities (see figure 4.2). This way, a ranking of interaction qualities emerges that can be considered for selecting ideas or iterating concepts. The argumentation that interviewees will give accordingly provides a lot of qualitative data. The value drivers are constructed from all findings gathered in the SWOT analysis (from literature and previous studies from Philips) (see Appendix E).

The interviewees for this semi-structured interview are introduced in an overview below. Through snowball sampling, a total of four respondents that matched the selection requirements were found. An interview guide, a consent form, and an introduction interview brief are given in the appendix F.

Em. Prof. Dr. Jack Jakimowicz	Professor of safety in healthcare – TU Delft
Annemiek Monhemius	Clinical application specialist – Philips
Robert van Overbeek	Ex-vascular lab technician & Clinical specialist – Philips
MD. PhD. Kirsten Huntjens	Ex-vascular surgeon & Clinical specialist - Philips

Table 4.1 - Interviewees that are interviewed



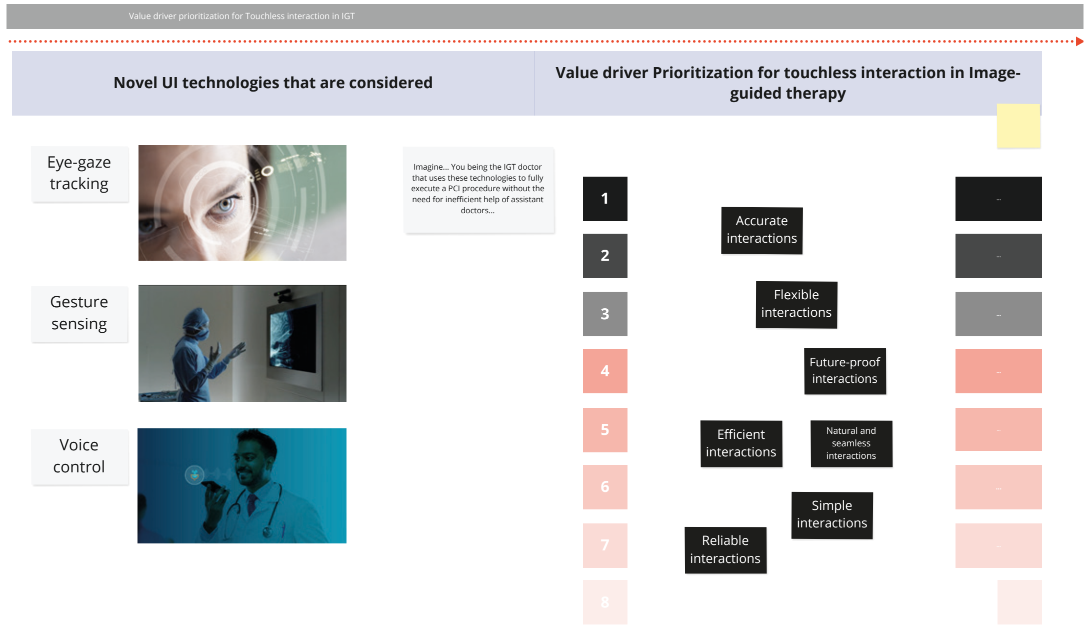
"One of the major barriers on using your technology is that physicians rely on staff, they cant do things themselves in there, and that takes time."

what is your perspective on this indirect HCI?

How would you rate inefficiency of this indirect interaction? (PRIORITEIT) And why? (1 = efficient and 10 = inefficient)

Do you see this as something that can be improved? And how/why?

Figure 4.1 - A workshop exercise to validate the opportunity scope



Imagine... You being the IGT doctor that uses these technologies to fully execute a PCI procedure without the need for inefficient help of assistant doctors...

Figure 4.2 - A workshop exercise to prioritize value drivers for implementing touchless interaction

04 - 2 **Analysis from results**

The results from these interviews and workshops are analysed and captured below. Validation of the opportunity focus is assessed with Em. Prof. dr. Jack Jakimowicz (see Appendix F) by discussing and rating specific indirect HCI situations during PCI procedures. A prioritization of experience drivers for touchless interaction is made with all four interviewees.

Validation of opportunity focus

The opportunity focus is based on a valid problem in the context of IGT, according to Jack Jakimowicz (see figure 4.3). This is also confirmed through discussing several examples of indirect HCI situations during procedures. The most important bottlenecks being changing the layout of the screen and measures distances accurately. These are situations in which most complications arise and lead to time-consuming clarification. Additionally, some situations are rated more significant than others because of a dependency on whether a procedural step directly contributes to the procedure's progress.

Prioritization of experience drivers for touchless interaction

The experience drivers for touchless interaction were overall similarly ranked by the interviewees. By giving the positions a specific score, certain drivers are valued more than others. For an overview of the total scores per value drivers (see figure 4.4). The top four value drivers that resulted from this interview are considered criteria on which ideas and concepts can be assessed. The reasons for the specific rankings gave a lot of rich insights into values and considerations for doctors in the context of IGT. In the next chapter, those insights are presented in several categories.

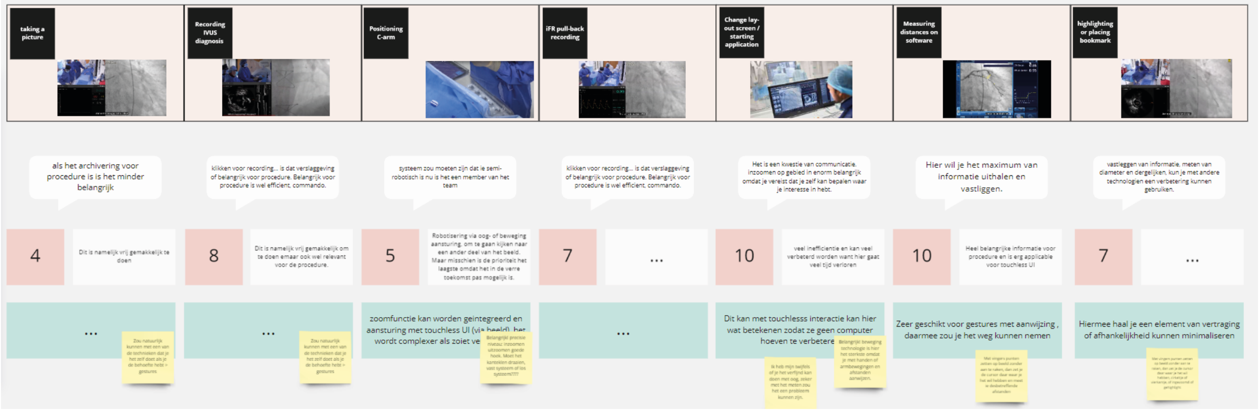


Figure 4.3 - Results of a workshop exercise to validate the opportunity scope

Figure 4.4 - Results of a workshop exercise to prioritize value drivers for implementing touchless interaction

04 - 3 Design guidelines

An overview can be created of the most important insights and guidelines within the design scope from all analyses and interviews. Looking back at the SWOT analysis, the future of IGT, the interaction analysis and the interviews, the most important considerations for ideation are mapped below. For the whole design guidelines analysis, see Appendix G. An important distinction is made between 'design requirements', 'design considerations' and 'design challenges'. Design requirements are essential to be captured in the final design solutions. The design considerations are elements and insights that can be taken into account during idea brainstorming. Design challenges provide us with several potential barriers that should be overcome over time.

Design requirements

- The interaction should reduce inefficiencies by taking away doctors' biggest frustration in IGT by minimizing dependency on staff and reducing indirect HCI.
- The interaction should be reliable to realize consistent results.
- The interaction should be accurate to optimize preciseness.
- The interaction should be natural and seamless to achieve intuitive interplay between human and computer.
- The actions to interactions with the computer should be simple, comprehensive and easy to use.

Design considerations

- There should be an immediate value noticeable with this interaction.
- The interaction should be comfortable for the user.
- For a successful interaction, the system should provide feedback.
- There should always be the possibility to fall back on the standard procedures with standard interactions.
- The technologies should be integrated into the systems within the cath lab.
- Most relevant interactional opportunities are: changing the layout of the screen and measuring distances.
- The importance of IGT is growing since more and more procedures can and will happen in these contexts. Therefore, it should provide agile and developing solutions.

Design challenges

- A training aspect should be taken into account for the interactions, to be executed successfully in practice.
- Differences in workflow, execution and staff during these procedures, between different hospitals, causes complexities for use.
- Irregular use and other differences in medical disciplines make it challenging to adjust solutions to everyone using the systems and devices.
- The multi-user environment could cause problems for interactions in this context.
- The ambient background noises during these procedures can cause complexities during interaction with voice.
- The interaction should be aligned, tested and evaluated with the direct context in which it is used.

04 - 4 Ideation and selection

Ideation process

For the ideation phase, an online workshop is organized with employees from Philips working on several innovative design projects within the context of IGT. A total of 9 people will be ideating on concrete ideas for certain opportunity areas that resulted from the interaction analysis. After presenting the analysis and its results, a brainstorm will be done on three related opportunity areas. After this initial ideation workshop, the ideas will be clustered and synthesized into several concepts with a storyboard in a subsequent session. For all the brainstorm results, see Appendix H.

Selection process

To select the right concepts that are aligned with the perspective of the important stakeholders within the context of IGT, the results from the workshop are used. Therefore, the most important interactional values will be assessed per concept. This will allow for the most optimal selection of concepts in line with the values and needs of the most important stakeholders.

04

CHAPTER CONCLUSION

In conclusion, this chapter was mainly dedicated to understanding the needs and wishes of the end-uses, the doctors in the context of IGT. Therefore, a semi-structured interview was set up in combination with some interactive workshop exercises. Four different perspectives from different stakeholders were gathered that were all relevant within this context of IGT. By analysing the interview and workshop results, certain conclusions could be drawn that were useful for the upcoming phases. These insights were translated towards design guidelines that are divided into three categories: design requirements, design considerations and design challenges. Another important result from the interview was a prioritization, from the interviewee's perspective, of interactional values that are most important when implementing touchless UI solutions. This ranking is used to assess and synthesize the concepts from the ideation.

The developed concepts are presented in the upcoming phase, assessed and aligned to synthesize and integrate them into the roadmap.

IMAGINE take-aways

Shaping the framework for qualitative research
Gaining a deep understanding of the end-user
Obtaining most important value drivers for implementing touchless interaction
Deriving design guidelines that can be used to validate conepts
Idea generation

05 DESIGN

This chapter is about introducing designs propositions and alignment with the future context of IGT. Several design implications are provided that resulted from the ideation brainstorm. By giving an overview of these concepts and their functional benefits, the value for implementing is addressed. Synthesizing these concepts into an implementation strategy that aligns with the future vision is important before translating these ideas into future scenarios. The future scenarios in this chapter address the alignment with the developing healthcare landscape and related initial horizons of the roadmap. At the end of this chapter, a strategic overview is given to address the value propositions for these concepts and services to achieve the future vision that is defined in chapter 3. In conclusion, this chapter provides a basis for the development of a preliminary prototype of a strategic roadmap.

05 - 1 **Design implications**

Figure 5.1 - Resulting ideas from brainstorming session with 12 people from Philips

In this subchapter, design implications are presented that resulted from the brainstorm. During the first ideation session with 12 participants of Philips, 115 ideas got written down see figure 5.1. In the second session, every team chose 3 (combined) ideas to elaborate further on. This resulted in 9 concepts that sometimes had some overlap. By iterating, clustering and assessing the value drivers, a total of 5 selected concepts remain.

The five selected concepts are elaborated in this chapter to briefly explain the functional benefits and value by providing a brief description, technological features, and resources. Additionally, a concept visual is made for every concept to give a deeper understanding of the interactional use within the context of IGT.

Concept 1 - Eye-indication pointer

This concept addresses the time-consuming and error-prone indicatory communication between stakeholders in the cath lab. Since efficient and precise communication is such an important element within this context, it is very desirable to have indication capabilities that are powerful communication tools. On average, these situations occur around 5 times in a procedure, so improving it can significantly reduce time spent on clarification. It uses gesture recognition to analyse if someone is pointing at the screen. If that is the case, it uses eye-gaze technology to accurately calibrate the position of the point of interest. This way, everyone can see what someone is pointing at. The technologies mainly use cameras and software for gesture detection and gaze tracking. Since this interaction is already quite natural, it is not expected that training is needed.

EYE-INDICATION POINTER

"The interaction should be natural, reliable and most of all, the doctors have to see the immediate and direct value." – Annemiek Monhemius, Clinical application specialist – Philips.

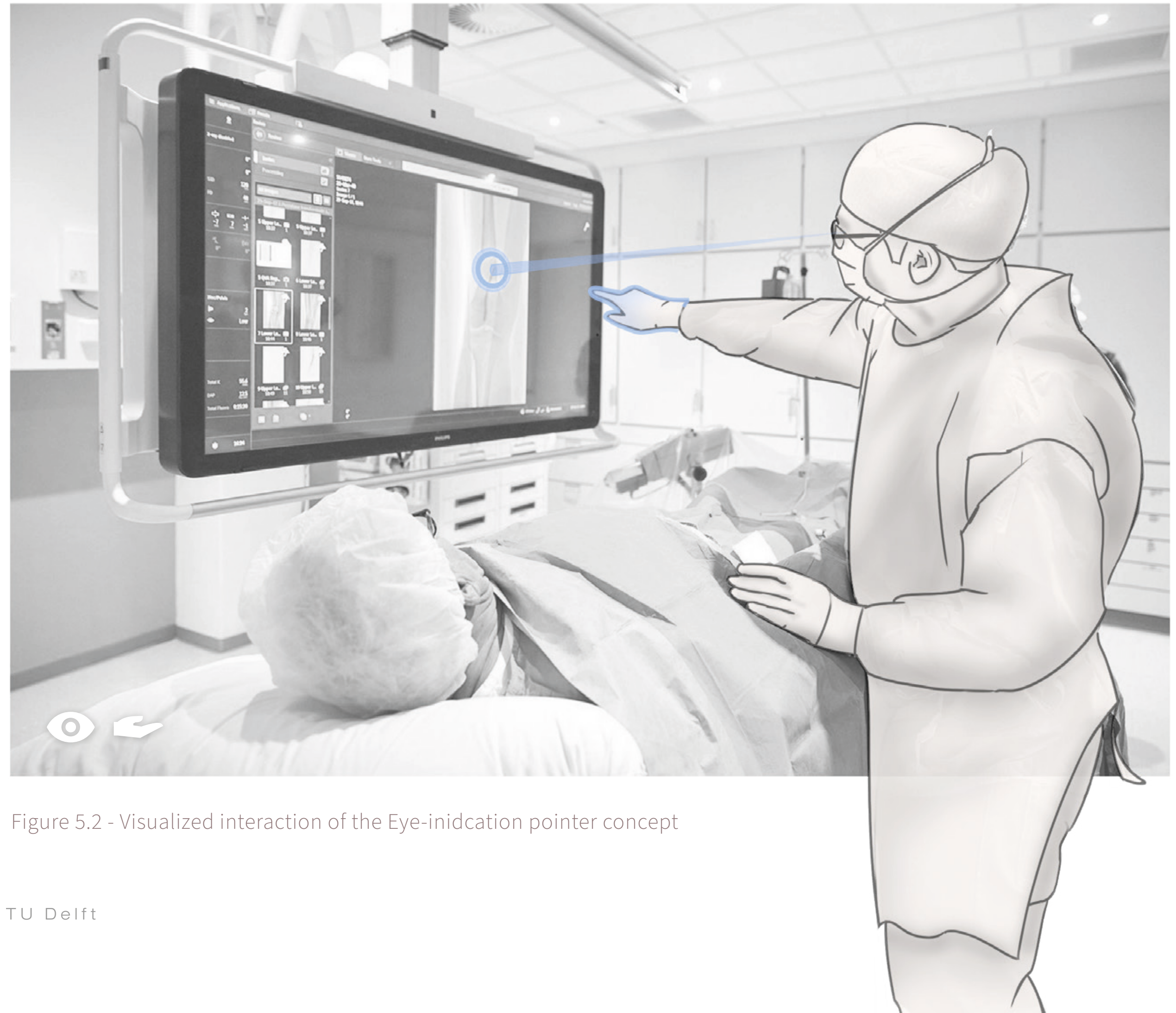


Figure 5.2 - Visualized interaction of the Eye-inidcation pointer concept

Concept 2 - Visual live captioning

This implication offers a general solution to communication inefficiencies in the cath lab. Since many interactions (60%) are based on verbal communication, the opportunity for this concept is significant. The chaotic and complex environment with multiple stakeholders and ambient noise create opportunities for effective communication. The direct value of this concept is minimizing the miscommunications, frustrations and enhancing workflow. The technology records what is being said to specific stakeholders and projects it on a window or screen with the addressed stakeholders. This way, there is a visually displayed textual back-up of communicational human interaction between specified roles in the cath lab. These questions, calls-to-action or announcements are displayed for several seconds to avoid being distracted during the procedure. The main barrier is speech-to-text processing in this complex and chaotic environment.

> *"Intraoperative communication is often error-prone and time consuming since the other stakeholder has to understand perfectly what you are requesting." – Em. Prof. dr. Jack Jakimowicz, Professor of safety in healthcare – TU Delft.*

VISUAL LIVE CAPTIONING

Figure 5.3 - Visualized interaction of the Visual live captioning concept

Concept 3 - Visual procedural reference log

This concept is beneficial for intraoperative planning and procedural logging. The idea is to visually represent 'localised' commands and actions over time to guide the procedure and visually document it simultaneously. This way, bookmarking, commands, eye-gaze tracking, software applications, actions, recorded voice messages, etcetera can be mapped over time. Now doctors can scroll back in time to see what someone has commanded of where someone has looked on-screen. This shows the overview of the process of the procedure that can be linked to the patient. In the long term, it can be used for procedure prediction. The bottleneck with this concept is gathering all the different information streams and synthesizing this into one coherent procedure overview.

> *"Within Image-guided therapy, there is a need for refinement and application of improved materials and tools." – Em. Prof. dr. Jack Jakimowicz, Professor of safety in healthcare – TU Delft.*

VISUAL PROCEDURAL REFERENCE LOG

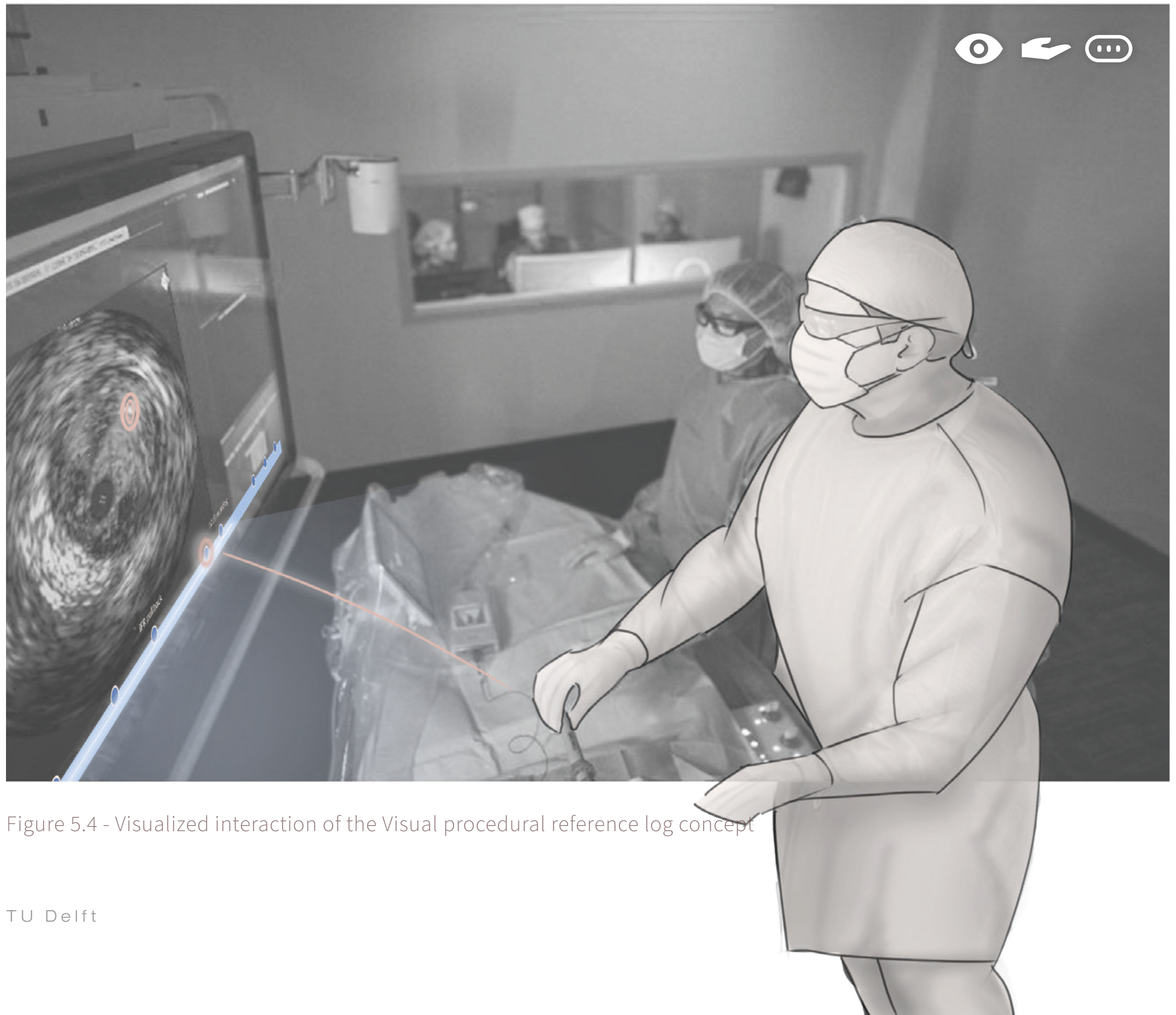


Figure 5.4 - Visualized interaction of the Visual procedural reference log concept

Concept 4 - Screen manipulation

This concept is based on the most occurring situation of indirect HCI during PCI procedures: asking for a change in screen layout. Often, these requests are time-consuming, error-prone and leading to inefficiencies. Sometimes, the doctor gets frustrated when he is not in control, while the actions of the supporting healthcare staff take time. If these actions can be done by himself, it would lead to a more efficient and reliable workflow. With the room recognizing who is in control, gestures can be executed to change the layout and manipulate images. Think about familiar gestural interaction like swiping, pinching, rotating, zooming, etcetera that can be recognized through cameras. With eye-gaze technologies, it is analysed what image is manipulated and what screen is replaced by another. This combination allows for an essential confirmative interaction style that makes these touchless interactions more reliable and usable. The main barrier with the use of this system would be multiple stakeholders and an extensive gesture language set. Therefore, it is expected that some training has to happen to familiarize doctors with using these systems.

SCREEN MANIPULATION

"The doctor's main focus is always the screen in IGT." – Robert van Overbeek, Ex-vascular lab technician & Clinical specialist – Philips.

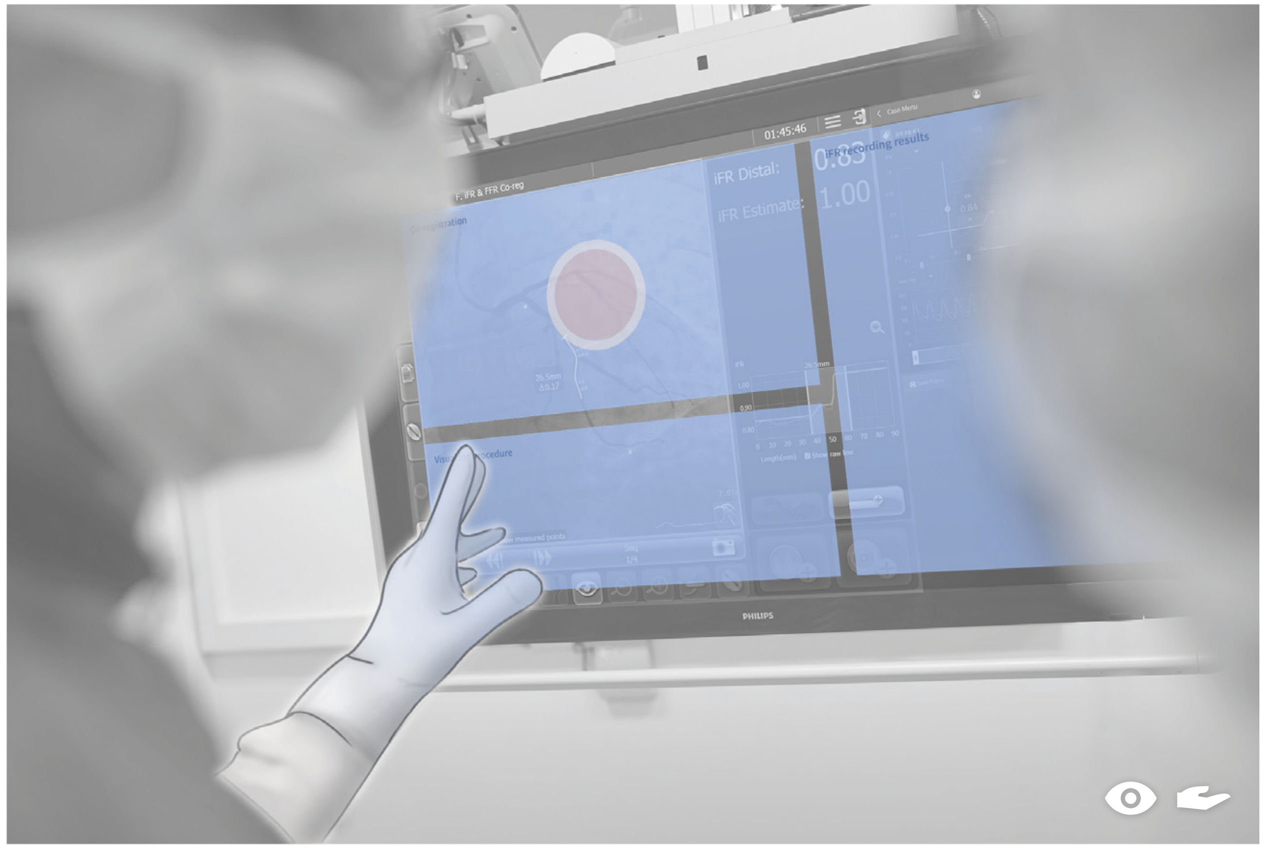


Figure 5.5 - Visualized interaction of the Screen manipulation concept

Concept 5 - Virtual assistant

The virtual assistant concept is based on replacing more and more situations in which indirect HCI is happening currently. Sometimes, the requests that doctors do are time-consuming, error-prone and leading to inefficiencies. It is assumed that in the future, the assistant's functionalities can replace one or more of the necessary stakeholders from the IGT context without the loss of time efficiency. By looking at the virtual assistant icon, an avatar pops up that initiates a voice UI to provide support and guidance during procedures. By combining eye-gaze, gesture sensing and voice control, algorithms can derive the necessary information from the input to give live support in activities like measuring distances, analysing application outputs, predicting stent length, etcetera without inefficiencies. Developing advanced software and technologies like these will cost a lot of time and money. However, in the long term, it can reduce the costs and time necessary for IGT procedures.

VIRTUAL ASSISTANT

"In an OR setting in most cases there is an experienced team which will assist you during the procedure. However, if this is not the case due to circumstances it can be difficult and time-consuming if you can't rely fully on your team members." – Kirsten Huntjens, Ex-vascular surgeon & Clinical specialist - Philips.

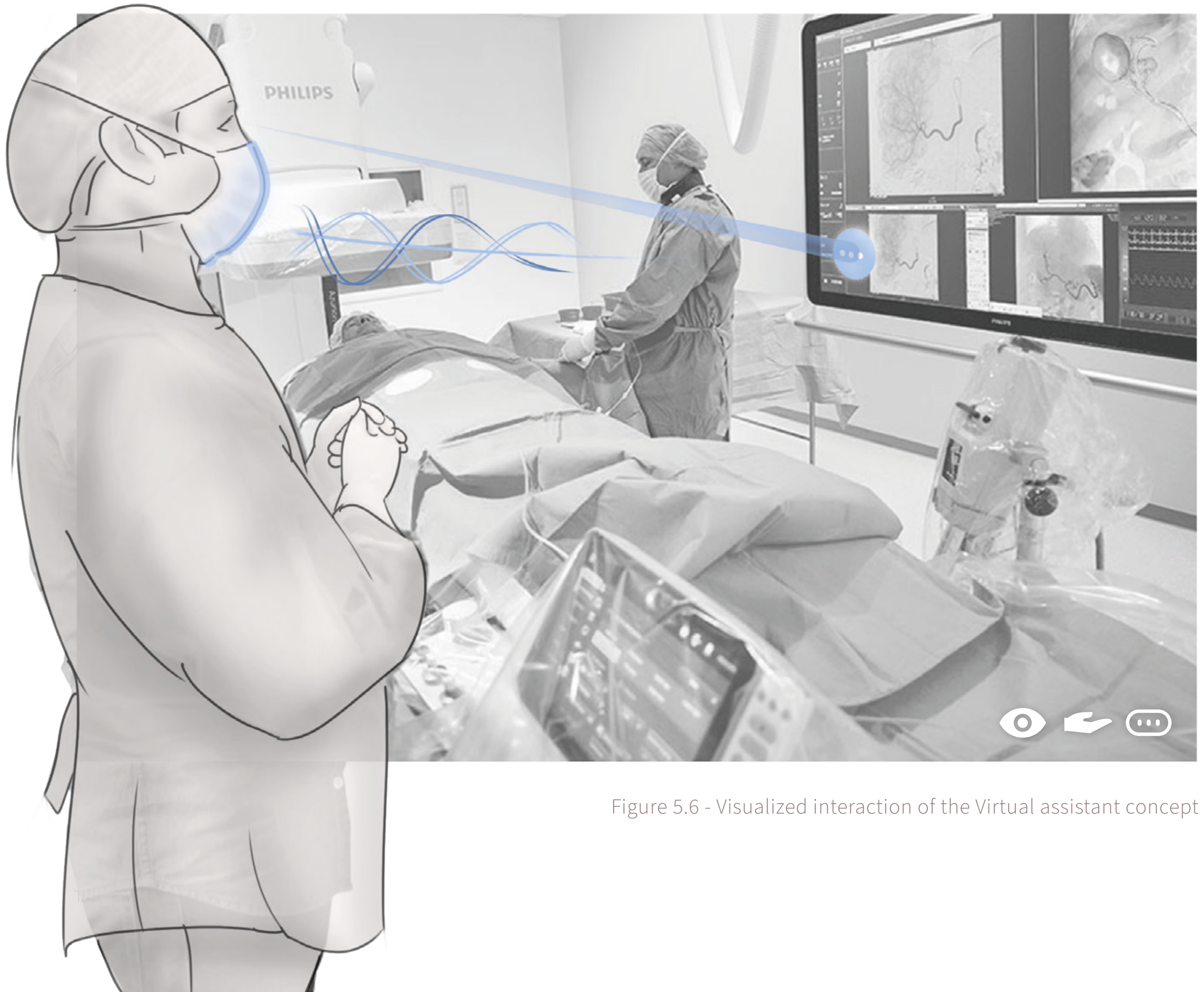


Figure 5.6 - Visualized interaction of the Virtual assistant concept

05 - 2 **Synthesis of design**

To create coherency in the implementation possibilities for these concepts, they should be synthesized appropriately. In this part, the design implications are aligned, prioritized and developed further over time. Since the final roadmap introduces developments in the future healthcare landscape, these concepts are implemented at specific moments in time to match the current context and to be aligned with the direction of the future vision.

Assessment of the design implications

Several value drivers are prioritized during the qualitative research as the most important values for implementing touchless interactions. The top four are considered during assessing the design implications: reliability, accuracy, natural and seamlessness (intuitiveness), and simplicity. An averaged implementation score can be established by rating these values for every concept from 1-10. These implementation scores indicate an 'overall trust' in every concept. The following theory is adopted: the higher the implementation scores, the higher the 'overall trust' for each concept, resulting in earlier implementation possibilities (see figure 5.7). For the full assessment, see Appendix I.

The first design implication, **'eye indication pointer'**, receives an averaged implementation score of **9,8**. This is very high since this interaction is very intuitive and simple. The reliability and accuracy are expected to be increased because these technologies already have the capabilities needed for this interaction to be realized. This concept could develop over time by being able to track and operate multiple people. Also, zooming in when it is desirable can be a functionality that could extend this concept.

The **'visual chatbox'** receives an overall implementation score of **8,8**. Since it is a supporting and passive feature during procedures, it is considered simple. It allows for textual conversation backup that is considered natural and assumed to be accurate and reliable in the upcoming years. Possible development for this concept could be that stakeholders only see the messages directed to them for themselves.

The **'visual log'** concept is assessed with an average score of **7,5**. This concept's base principle is very simple and supportive. It facilitates a visual backup of the procedure with highlighted bookmarks, commands and actions that are recorded. This way, the user has the ability to go back in time to see the interactions that happened. The future development of this idea is that the logging file is linked to the patient's profile and facilitates a predicted overview of the procedure planning. Additionally, capturing all actions can lead to improved efficiency since less time has to be spent on postoperative documenting of the procedure.

The **'screen manipulation'** implication is an essential concept for the design scope of this project. It addresses the core of the most relevant opportunity to equip the doctor with more direct interactional control over the screen layout. It receives an overall implementation score of **7**. The concept allows for less reliability and more efficiency during procedures in the cath lab. Since it is assumed that this interaction requires some optimization of technologies, training and familiarity, it is not yet that simple. Therefore, later implementation is more convenient. Future developments could be that more functionalities that require indirect HCI are replaced with interactions that facilitate direct control to the main doctor. The interactional language is expected to be similar to the interaction style presented in this concept.

The concept of the **'virtual assistant'** receives an overall implementation grade of **6,3**. That is because the system is not expected to be very reliable and simple yet. Therefore, it needs appropriate optimization and development to support the main doctor accurately in his/her needs. When this can be realized, a natural conversation is expected to be the means of interaction with the assistant. This results in a high potential on a long term basis. Another future development of this system could be that the assistant is an actual virtual person that interacts with you when you specifically need it.

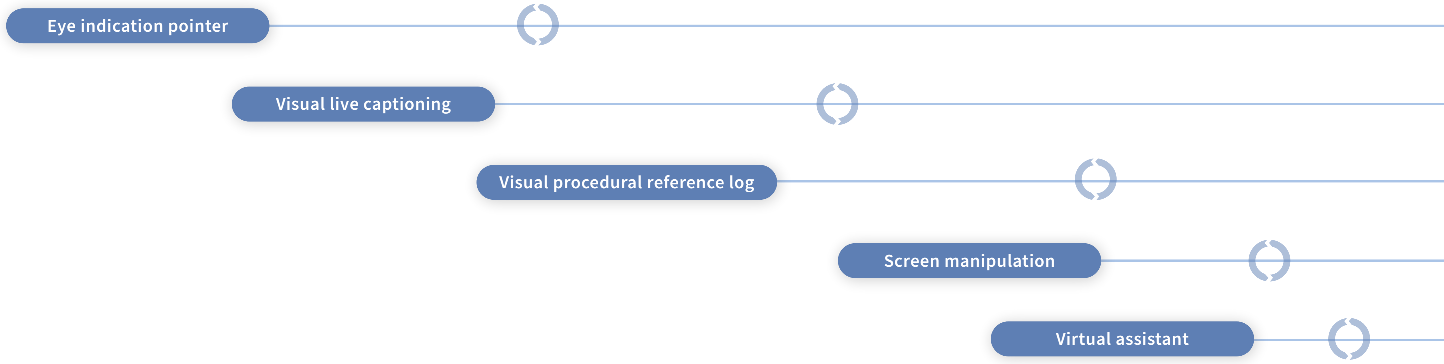


Figure 5.7 - Visual representation of synthesis of design implications

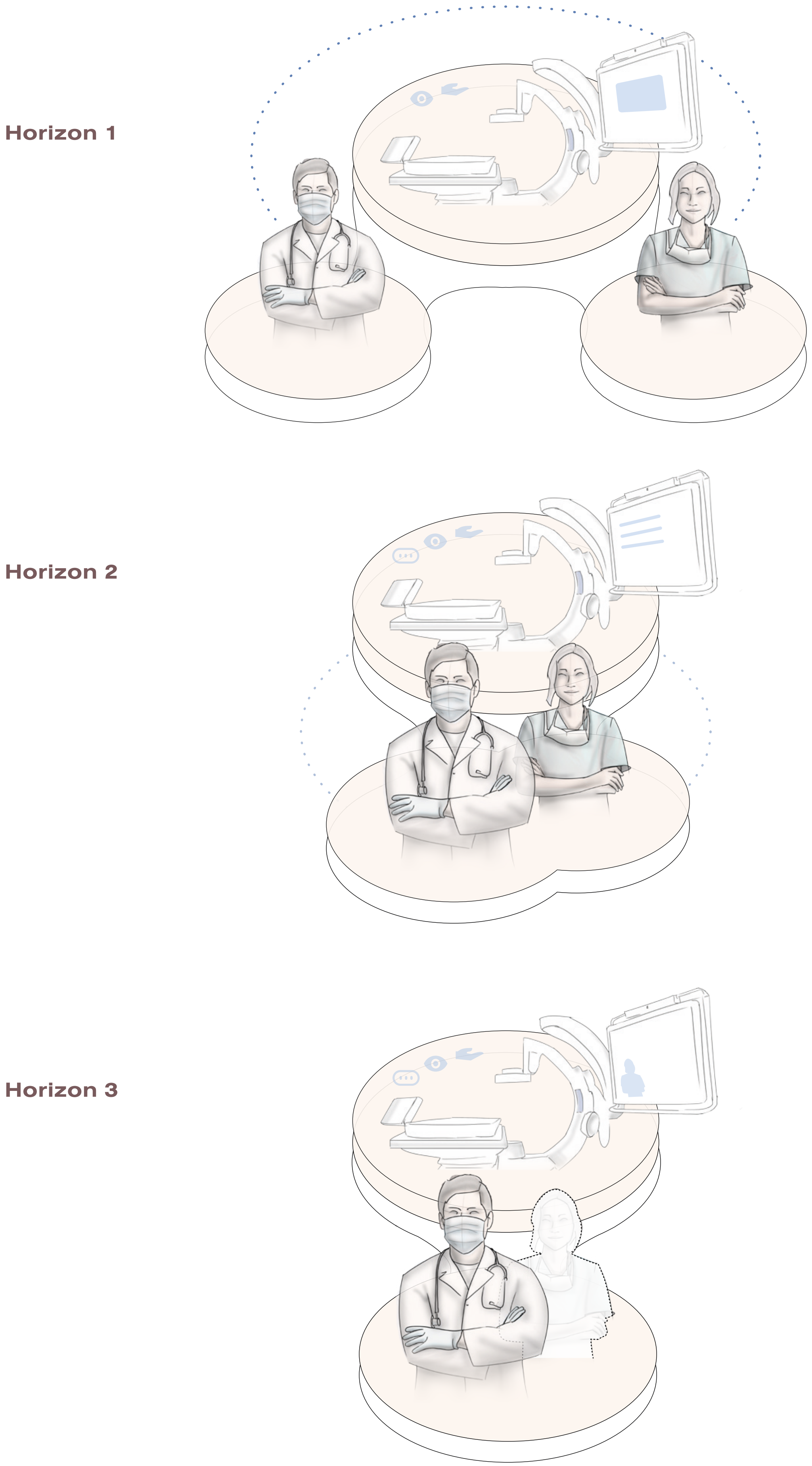


Figure 5.8 - Visual elaboration on horzions in the near future.

Alignment with future vision

Over time, the synthesis and development of these concepts establish valuable and balanced steps towards the direction of the future vision. In order to elaborate on this alignment, the road towards the future vision is explained in 3 considered horizons (see figure 5.8).

'Reinforcing the connection with technology' - Horizon 1 – 2023

This horizon is about reinforcing the bridge between human and technology. By improving the infrastructure and communication, inefficiencies can be lowered, and teamwork between stakeholders can be improved. This results in an optimized workflow in which fewer bottlenecks will take place. At the end of this horizon, it is assumed that … less mistakes will be made, resulting in an improved procedure with a decreased time of … .

'Aligning stakeholders and improving workfflow through technology' - Horizon 2 – 2026

In the second horizon, a situation is described in which the connection between human and technology has got even stronger. Therefore, it allows for optimized alignment of stakeholders in the context. Almost all inefficiencies are prevented, and everyone in the cath lab actively participates when needed in an even more optimal workflow. Additionally, some indirect HCI bottlenecks are minimized through innovations and accurate alignment of human and technology. At the end of this horizon, it is assumed that … less mistakes will be made, resulting in an improved procedure with a decreased time of … .

'Optimization of workflow through merging innovations with teamwork' - Horizon 3 – 2030

In the last horizon, the team's connection between human and technology is so strong that the doctor feels in total control without losing any time. Several innovative ideas merge together into an optimized workflow that excludes the need for assistants. Almost all indirect HCI are prevented with the implementation of the concepts mentioned. At the end of this horizon, it is assumed that … less mistakes will be made, resulting in an improved procedure with a decreased time of … .

This road towards the future vision gives an overview of the strategic path that should be considered when designing for IGT. In the following subchapter, future scenarios are presented based on the horizons to elaborate on contextual factors and alignment between design propositions and the overall development in those years.

05 - 3 **Future Scenarios**

To elaborate a bit more in-depth on these horizons, a future scenario can be described. This subchapter addresses how both the design implications and their synthesis come together with the healthcare landscape and the general goal of the future horizons. These scenarios are described by touching upon several parameters shown in the related horizon visual. Additionally, resources and service propositions are introduced to create a holistic perspective on future circumstances. Finally, for these Future scenarios to be in line with the theory of Design roadmapping (Simonse, 2017), the strategic life cycles are considered (see figure 5.9)

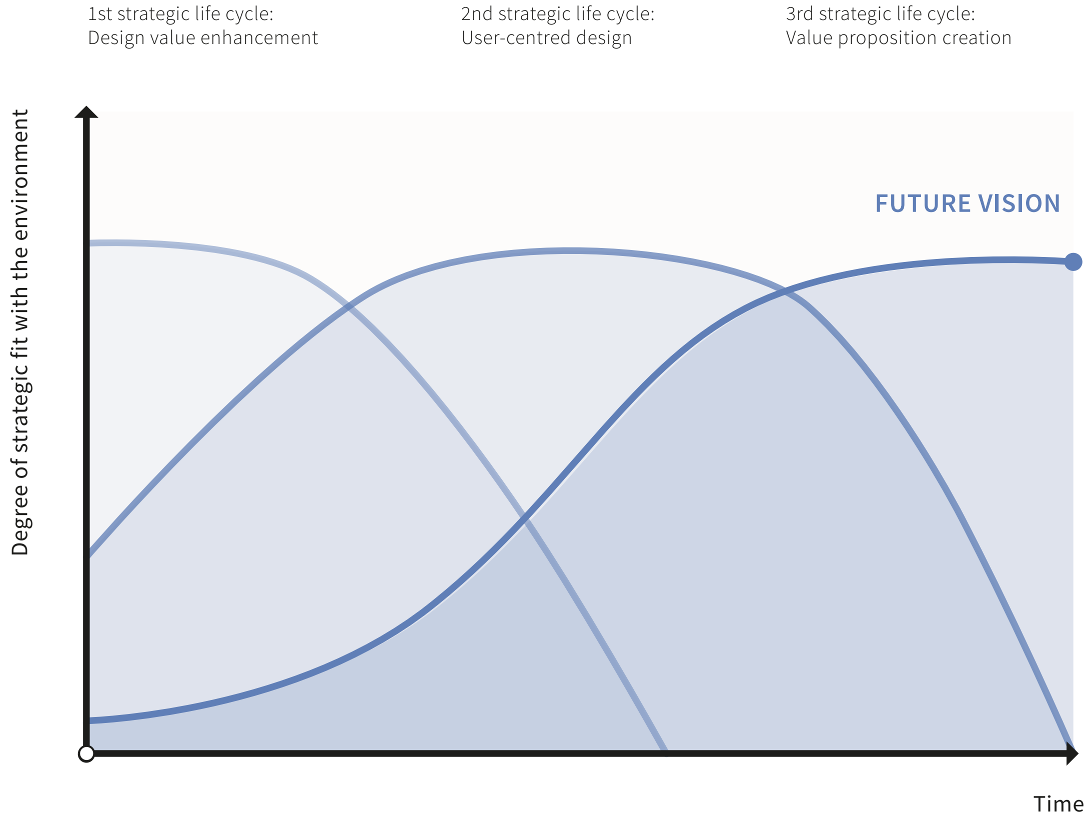


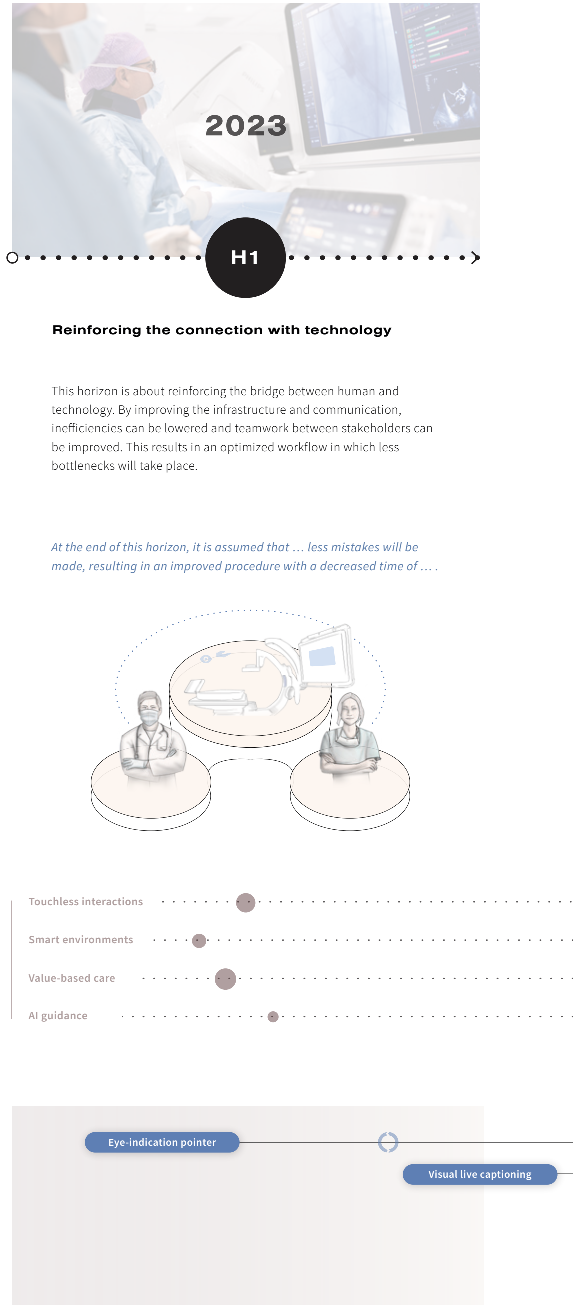
Figure 5.9 - Strategic life cycles of the design roadmapping theory of Simonse (2017)

Future scenario 1 - Design value enhancement

Horizon 1 'Reinforcing the connection with technology'

In 2023, the connection between human and technology in the cath lab is reinforced. By improving this connection, inefficiencies are minimized, and the stakeholders in the cath lab are enabled to work together more effectively. Proposed design implications like the 'eye-indication pointer' and the 'visual chatbox' are concrete concepts in line with this horizon's description. Therefore, some touchless interaction technologies are implemented in very simple ways to support the specialized healthcare team. Without having too significant functions, these technologies allow for fewer miscommunications and inefficiencies. The integration of these systems in the IGT context detect specific signals and act upon them to deliver good interaction. This is how the experience of the healthcare staff is improved. Furthermore, some AI algorithms are used to detect speech and gesture sets in order to facilitate seamless interaction.

Since it is not possible to implement these technologies right away, several propositions can be made. Before implementing the suggested design implications, these propositions should be considered to integrate them in a proper, deliberate way. For doctors, it is important to be up to date with the technological updates on the Azurion system. Therefore, an e-learning for the functionalities of both design implications is recommended. The integration of these concepts into training labs where doctors are familiarized with the system and devices is also recommended. Additionally, it could be interesting to invest in research on noise-cancelling in the cath lab to reduce background noise interference for future voice interaction. This would also remove barriers for other future design implications that operate through voice control.



Reinforcing the connection with technology

This horizon is about reinforcing the bridge between human and technology. By improving the infrastructure and communication, inefficiencies can be lowered and teamwork between stakeholders can be improved. This results in an optimized workflow in which less bottlenecks will take place.

At the end of this horizon, it is assumed that … less mistakes will be made, resulting in an improved procedure with a decreased time of … .

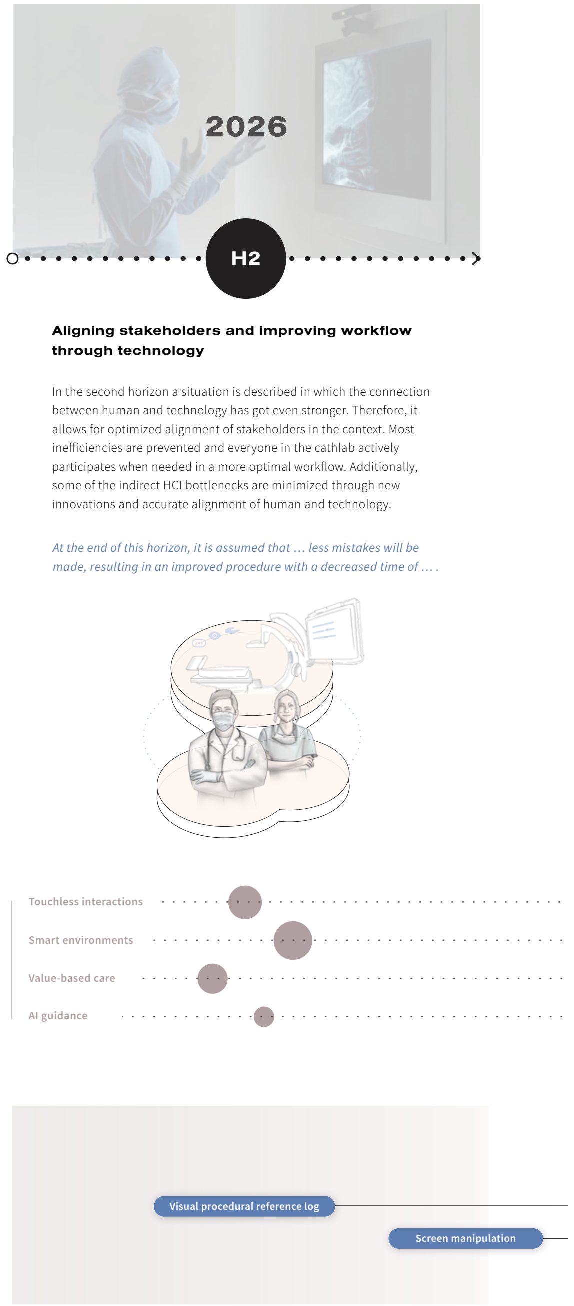
Figure 5.10 - Future scenario of horizon 1 synthesized

Future scenario 2 - User-centred design

Horizon 2 'Aligning stakeholders and improving workflow through technology'

In 2026, the stakeholders in the cath lab are aligned, and the overall workflow is improved by implementing new technologies. Improving stakeholder alignment through technology helps the team to work even more efficiently. The proposed concepts 'visual log' and the 'screen manipulation' facilitate these workflow improvements. Therefore, the description of the horizon matches the intention of implementing these technologies. Since more (complex) touchless interaction are introduced, this will play a more significant role in the healthcare landscape. The IGT environment is slowly becoming a smart environment that keeps track of the procedure and interactions happening, allowing for a seamless continuation of the procedure. Implemented AI algorithms are slightly more significant than before, providing support to the healthcare staff and delivering possibilities for high-quality care.

The earlier mentioned e-learnings should be updated to the functionalities of these new concepts and the training labs. However, since the end-users did not get the chance yet to consciously familiarize themselves with touchless interaction, some touchless UI workshops can be provided by Philips. Additionally, since more innovations are going to take place, it would be even desirable to set up an AR/VR experience centre for doctors that shows what Philips is aiming for. Also it allows the doctors to accustom to these changes.



Aligning stakeholders and improving workflow through technology

In the second horizon a situation is described in which the connection between human and technology has got even stronger. Therefore, it allows for optimized alignment of stakeholders in the context. Most inefficiencies are prevented and everyone in the cathlab actively participates when needed in a more optimal workflow. Additionally, some of the indirect HCI bottlenecks are minimized through new innovations and accurate alignment of human and technology.

At the end of this horizon, it is assumed that … less mistakes will be made, resulting in an improved procedure with a decreased time of … .

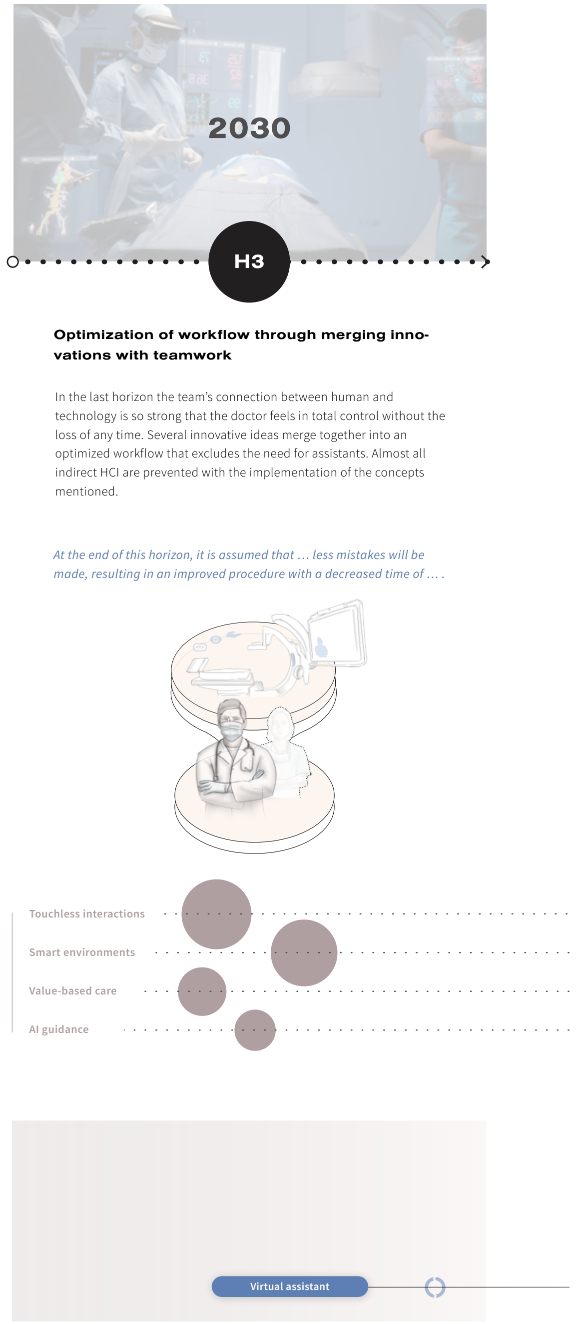
Figure 5.11 - Future scenario of horizon 2 synthesized

Future scenario 3 - Value proposition creation

Horizon 3 'Optimization of workflow through merging touchless innovations with teamwork'

In 2030, optimization of the workflow is the primary goal. When merging the implementation of new technologies and the development of the existing concepts with improved teamwork, this goal can be aspired to. The concept 'virtual assistant' embodies the decrease in reliability on your healthcare staff. With all the development it has got over the years, it allows for reliable, accurate and desirable additions to the workflow of the doctor. Within this horizon, every proposed concept comes together, making touchless interaction increasingly significant within this timeframe. Since technologies and sensors are integrated into the existing systems of Philips, all necessary ingredients are captured within this smart environment. The virtual assistant is completely AI guided to determine the doctor's needs at specific moments in the procedure. This way, the quality of care is improved.

As a proposition for Philips, again, the e-learnings and training labs should be up to date with the newest technological implementations. In addition, since doctors may need to adapt to being supported by a virtual assistant, some introduction session would be desirable.



Optimization of workflow through merging innovations with teamwork

In the last horizon the team's connection between human and technology is so strong that the doctor feels in total control without the loss of any time. Several innovative ideas merge together into an optimized workflow that excludes the need for assistants. Almost all indirect HCI are prevented with the implementation of the concepts mentioned.

At the end of this horizon, it is assumed that … less mistakes will be made, resulting in an improved procedure with a decreased time of … .

Figure 5.12 - Future scenario of horizon 3 synthesized

05 - 4 **Service propositions**

To align these future scenarios with Philips' important role in this process, several actions are presented in this chapter to seamlessly integrate the concepts within the roadmap. Therefore, this subchapter will describe how Philips can give meaning to seamless innovation within IGT. Several service propositions are mentioned in the previous chapter that can add value for this purpose. These propositions are elaborated by explaining ***what*** it is about, ***why*** it adds value and ***when*** it should be implemented, ***how*** it should be implemented.

E-learning

what	Since there already are e-learnings for the Azurion system, it is necessary to update these when new functionalities are introduced.
why	This way, the doctors stay theoretically up-to-date with the newest innovations and relate to the system a bit more.
when	It is necessary that these updates take place right before the innovation is implemented. When it is implemented later or earlier, it loses value.
how	Since current e-learnings are not followed that often by doctors. It is necessary that this is stimulated even more by both Philips and the hospital. For it to be used frequently, added value has to be clear, and it should be fun.

Training labs

what	Training labs are functional cath labs for training purposes that should be implemented in spare rooms in hospitals or un-used OR's.
why	Since end-users are often in the hospital, the training is brought to their workspace. This way, the healthcare staff can get familiar with the system and improve teamwork. From the interaction analysis and interviews, it is expected to be very useful to train doctors to properly handle functionalities of the Azurion system.
when	It is important to improve training services as soon as possible since it is an existing and acknowledged barrier that can already be minimized.
how	By providing more clinical application specialists to hospitals and efficiently managing un-used OR's or separate cath labs as training context.

Noise-cancelling

what	If noise-cancelling in the OR can prevent interference for voice-control systems, it would register commands and conversation more effectively.
why	Since it can be seen as an existing barrier for implementing voice UI in complex and chaotic environments.
when	It would be necessary to implement these technologies before conversational-based interactions happen in the cath lab. According to the roadmap, that is already quite soon. Therefore, early investing in research and technological development is recommended.
how	By levelling out the background noise, the functional voice commands can be recognised more effectively and reliably.

Touchless UI workshops

what	Touchless UI workshops are get-togethers of doctors and developers to show and experience procedures with these interactions.
why	Since more and more functionalities will be operated with touchless UI to improve efficiency and reliability, it is desired to familiarize the end-user with technologies like these. Additionally, the input can be gathered for iterating on these interactions.
when	Before touchless UI gets a significant role in procedures in IGT, it is important to already have educated end-users that these technologies have great potential to improve their work.
how	Mobile workshops in training labs in the hospitals will provide a low threshold attendance for doctors to experience these innovations.

AR/VR experience centre

what	The AR/VR experience centre will be a inspirational hub in which the newest innovations are simulated and presented.
why	It is important that doctors know in what direction Philips' IGT developments are going so that they become familiar with and relate to the long-term vision of Philips.
when	It would be valuable to launch such a centre when more complex and novel interactions are implemented in IGT. This way, doctors have a holistic idea of the roadmap towards the future and realize how current innovations already fit this direction.
how	This centre should be somewhere central that doctors can visit in their free time, much like a museum. The location should allow for a futuristic, fun and intriguing experience.

05

CHAPTER CONCLUSION

In conclusion, this chapter was about designing the building blocks of the final deliverable, the strategic roadmap. In total, five concepts are developed and presented that can be implemented over time. Some concepts are more futuristic than others, and others have more overtime development possibilities. The synthesis is based on an assessment of the concepts of the top four interactional values that resulted from the research in chapter 4. The concepts with the highest scoring average are expected to be implemented earlier. This synthesis will be assessed in the upcoming chapter. In order to align the future contextual landscape with technological developments, the direction of IGT in the future and the design implications, a future scenario is described to align the needs, resources and expectations. Several strategic propositions are made to create a fluent implementation strategy of the concepts for Philips.

The upcoming phase will be about assessing and aligning these preliminary elements of the roadmap in order to synthesize everything into one final holistic strategic roadmap that is substantiated by validations from different perspectives.

DESIGN take-aways

- Establishing concrete concepts with touchless interaction
- Synthesiszing these concepts to make an preliminary prioritization
- Implementation of these concepts into the future healthcare landscape
- Establishing service propositions to provide seamless integration into roadmap

06 DELIVER

This chapter is about aligning the roadmap and finalizing the research that has been done. By validating and assessing the different elements of the roadmap, a deeper understanding can be derived, and qualitative results are integrated into the roadmap. A final iteration is made on the alignment of this resulting overview going into the alignment with the company Philips. At the end of this chapter, the final roadmap is presented to provide guidance and strategic input for Philips. This is the final deliverable for this graduation project.

06 - 1 **Validation and assesment**

In order to validate the preliminary elements of the roadmap, a validation and assessment session is planned with two experts. By considering the different perspectives of these experts, reliable feedback can be gathered to synthesize the roadmap more valid. The first expert is **Atul Gupta**, the global chief medical officer of IGT at Philips. He provides insights from a high-level perspective, taking into account the medical business of IGT globally. The second expect is **Niels Bakker**, a marketing strategist and director of product management of IGT systems at Philips. He shares his perspective from a strategic point of view, taking into account the marketing and positioning of Philips' IGT strategies. The full validation (see Appendix J) will touch upon several essential aspects of this thesis; the concepts, the preliminary roadmap (see Appendix K) and the alignment with Philips. In the next chapter, this is used to establish business alignment.

Concept validation

In general, the concepts form an excellent basis to build a strategy on. Both experts map all concepts in a schematic overview in figure 6.1. The eye-indication pointer is a functionality that is already used often in medical situations. It received great feedback in use, however, the application is quite limited and specific. The screen manipulation concept is very valuable and desired by doctors. Additionally, if the virtual assistant concept works well, it is a very valuable proposition. This is mainly based on voice interaction, which is already feasible. Nevertheless, It is expected by both experts that a pro-active virtual assistant, backed up with extensive AI algorithms, will be possible in a later stage. Therefore a division can be established between a standard virtual assistant with specific tasks and commands and an advanced virtual assistant that is proactively tracking the workflow and bases its tasks on AI algorithms. The expected value of the concepts visual live captioning, and visual procedural reference log is less clear for the experts. Mainly because there are no specific use-cases mentioned in the concept description, if specific use-cases are found, it will allow for a great starting point for this concept. Over the years, the functionalities of these concepts can be transferred to more use-cases. Considering this philosophy, these concepts can still be very valuable.

Atul Gupta, MD.
Global Chief Medical Officer -
IGT at Philips

Niels Bakker
Marketing Strategist - IGT
systems at Philips

1 Eye-indication pointer
2 Visual live captioning
3 Visual procedural reference log
4 Screen manipulation
5 Virtual assitant (A - standard)
(B - advanced)

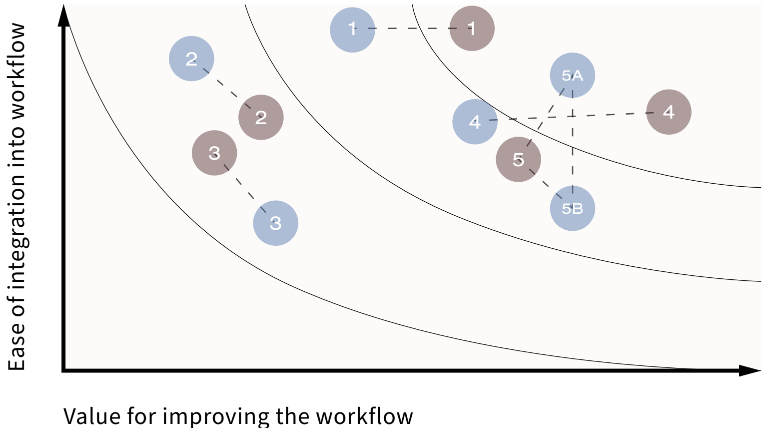


Figure 6.1 - Concept mapping from validation session

"If all technologies can be combined with the goal of making the interaction more natural, the integration into the workflow becomes easier." – Atul Gupta

"If the technological barrier is overcome, the integration of some concepts you mention becomes fairly easy."
– Niels Bakker

Roadmap validation

Regarding the experts, a roadmap should represent what is expected to happen over the years while substantiating that with the implementation of concepts and indicating values and benefits. This roadmap is considered a solid start, however, iterations are required to fill specific gaps. The initial description of the horizon is there, but the names could be changed to something more concrete. Additionally, the order in which the concepts are implemented is questioned by both experts. Both Niels and Atul address that the screen manipulation concept should be implemented in the first horizon. Since this concept is very desired by most doctors, easily implementable, and already technologically possible, it fits better into the goal of the first horizon. Also, the standard virtual assistant that is limited in use can already be implemented between the first and second horizon. Over the years, it can be developed into a fully functioning, pro-active virtual assistant. These changes should be made to align it correctly with the doctors' needs and capabilities, the development towards the future vision, and the technological capabilities of Philips.

"Considering usability for doctors, and integration into their workflow, in combination with the hurdles for Philips, I think that this revised order would be the appropriate order to implement those concepts."
- Atul Gupta

"The timing for implementing concepts is dependent on your perception towards them. If you are looking to implement an AI based concept, it will require more time to develop and to be usable." – Niels Bakker

Alignment with Philips

The alignment with Philips is considered to be essential for this roadmap since it increases the value when it is aligned with different projects and processes of the business. Therefore, the perception of alignment with Philips's strategy is validated by assessing several elements of the roadmap. Both experts expect the roadmap to be transferable to other suites of IGT, increasing the value of adopting this roadmap. The time pacing of the roadmap ought to be aligned with the time-pacing of existing roadmaps for IGT within Philips. This will provide a realistic implementation flow that provides reliable planning. Additionally, more concrete values and benefits should be established to indicate the relevance of the implementation of concepts for each horizon. Both the alignment of the time-pacing and business value is established in the next chapter about business alignment.

"This strategy would definitely be fully transportable to every section of IGT suites." – Atul Gupta

"You can't just make up business value for every concept, you really need to look into what it hypothetically solves and if that can be given a score." – Niels Bakker

06 - 2 **Business alignment**

In order to align the roadmap towards a business, a concrete value should be included in which the return of investment becomes clear. Therefore, in this chapter, a comparison is made with existing strategic roadmaps from within Philips. Firstly, the time-pacing of the horizons will be assessed. This will provide insights into the alignment considering technological developments and adaptation of concepts. Secondly, an estimated improvement claim is made to have a realistic target for 2035. Lastly, mapping concepts into a tension plot between clinical and operational performance will allow for scoring the value of the concepts on executive performance. If the application of this method is possible, it is an important tool to establish the quantified value of certain propositions.

Time-pacing

To align the time-pacing of the horizons of the resulting roadmap with earlier business roadmaps, a comparison is made with an existing strategic roadmap from Philips. Because of confidentiality reasons, this cannot be shared. In this time paced strategy, an argumentation of technological developments and business capabilities are addressed. It can be concluded that the current time-pacing is similar to the one of Philips' IGT strategy. Therefore, no adjustments are made regarding the specified years of the horizons and the concepts that are brought to the market in that period.

Estimated improvement claim for future vision

With the future vision functioning as an expression of the desired future (Simonse, 2017), a claim can be established functioning as a target for improving workflow efficiency based on this roadmap. An average PCI procedure that was considered in this project takes around 90 minutes. Taking into account the complex innovation in the healthcare environment, it is estimated that in 2035, the average duration of PCI procedures will account for 85% of the original average procedure time. So, because of improved executive performance (combination of clinical and operational performance), the standard procedure time (SPT) decreases from factor 1 to factor 0,85, resulting in a future **procedure time of 77 minutes**.

Concrete value per concept

Since concrete value and benefits are missing from the horizons, it is necessary to score the concepts on a tension plot. The two most important assessment variables for innovation in IGT are clinical performance (CP) and operational performance (OP). These parameters are scored with a value between 1 and 10. Mapping the concepts on these parameters results in an executive performance score for every concept (see figure 6.2).

Concept 1

4 - CP This concept allows for the possibility to execute procedures more accurate with this concept since everyone is easier on the same page. This will also result in more reliable procedures in which fewer possibilities are created that could lead to harmful mistakes.

8,5 – OP This concept allows for improved communication between stakeholders in the cath lab. The previously inefficient situation that is now improved occurred around five times per PCI procedure. Actions like measurements will become way more accurate and efficient (which is one of the most recognized problems in my opportunity validation during the interviews I did). Even though this is a very specific and limited use case, it will still add significant value, making the procedure more efficient.

Resulting executive performance: **14**

Concept 2

3 - CP This concept allows fewer miscommunications and errors originating from communication to happen. This results in improved clinical reliability since all stakeholders will be on the same page regarding the necessary actions.

7 - OP Regarding operational performance, this concept allows for more efficient procedure workflow since verbal communication does not have to be repeated. Additionally, specific stakeholders immediately receive specific tasks that they can execute.

Resulting executive performance: **11**

Concept 3

4 - CP This concept allows for an improved clinical performance since doctors can go back in time to validate and assess their previous actions. This way, more personalized care can be delivered to the patient, resulting in improved procedure accuracy.

5 - OP This concept allows for improved operational performance since it minimizes the chance of repeating unnecessary steps. These inefficiencies do not occur that often during the procedures that I observed, but it can be assumed that this visual backup will be comforting.

Resulting executive performance: **10**

1	Eye-indication pointer	
2	Visual live captioning	
3	Visual procedural reference log	
4	Screen manipulation	
5	Virtual assitant	(A - standard) (B - advanced)

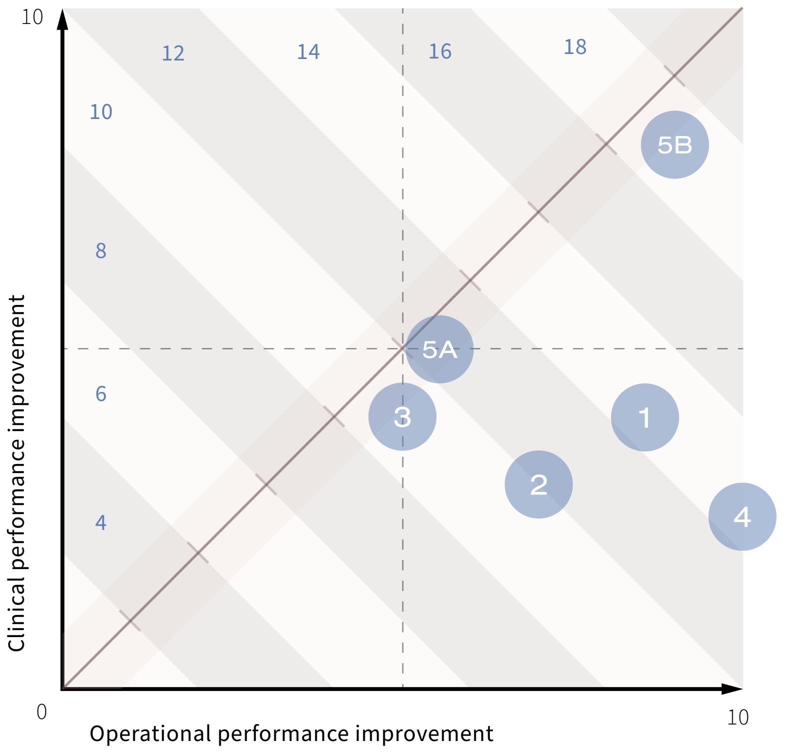


Figure 6.2 - Concept mapping in tension plot to asses concrete value on parameters CP and OP

Concept 4

2,5 - CP This concept allows for possible improvement in accuracy since the doctor now has control over what he sees on the screen. This way, the doctor can easily zoom in or start a new application via gestures. It is assumed that asking this to the technician is avoided because of the considered delay.

10 - OP This concept allows for a maximally improved operational performance. Since my interview research addresses this problem as the most urgent opportunities to improve for better workflow, it is very relevant to tackle the problem with a concept like this. Atul even mentioned: “I think that there is tremendous value in screen manipulation without a headset”.

Resulting executive performance: **14**

Concept 5

A) **5 – CP** This concept allows for a efficient analysis and simple functions/tasks that can be executed by a virtual assistant to increase consistency and clinical reliability. The concept is still passive and should be initiated through eye-gaze and voice commands.

5,5 – OP This concept allows for an increased workflow since the doctors do not have to explain the exact tasks to one of his/her colleagues. The virtual assistant is efficiently initiated.

Resulting executive performance: **12**

B) **8 – CP** This concept allows for an even more efficient workflow since the assistant becomes more proactive and provides valuable additions without distractions workflow. An increased personalisation, reliability and accuracy is achieved (through AI algorithms)

9 – OP This concept allows for an increased workflow since proactive suggestions are made (only when necessary), resulting in an aligned addition that fills the gaps that the doctor experiences.

Resulting executive performance: **18**

Synthesis of concrete value per horizon

The total of all concepts is an executive performance score of 79. This score is assumed to be the full 100% of the estimated and significant improvement of factor 0,15 on the SPT. The distribution of this total value over time indicates the percentual improvement per horizon.

After validation with Atul and Niels, concept 1 & 4 are introduced in **horizon 1**, resulting in an executive performance score of 28. Compared to the total executive performance scores, it results in a rounded **improvement claim of 35%** at the end of the first horizon.

In **horizon 2**, concepts 2, 3 & 5A are introduced to align stakeholders and provide technological innovation, resulting in an executive performance score of 33. When this value is added to the previous score and compared to the total executive performance scores, it results in a cumulative rounded **improvement claim of 75%** at the end of the second horizon.

Concept 5B is introduced in **horizon 3** to decrease dependency on staff, resulting in an executive performance score of 18. When this value is added to the previous score and compared to the total executive performance scores, it results in a cumulative rounded **improvement claim of 100%** at the end of this final horizon.

In conclusion, this indication of improvement distribution functions as a guideline. It can be used to validate if developments and results over time, are on track. If this is not the case, considered steps can be taken to achieve the upcoming targets indicated in the roadmap. In the next chapter, the final roadmap is presented.

06 - 3 Final roadmap

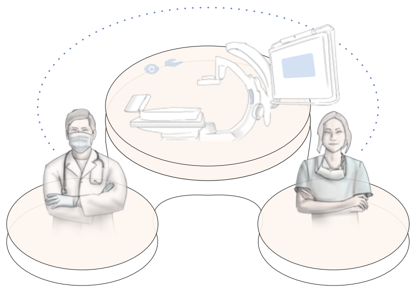
H1 · **H2** · **H3** · **FV**

Horizon elaboration

H1

Facilitation of technological improvements
Reinforcing the connection with technology

This horizon is about reinforcing the bridge between human and technology. By improving the infrastructure and communication, inefficiencies can be lowered and teamwork between stakeholders can be improved. This results in an optimized workflow in which less bottlenecks will take place.



H2

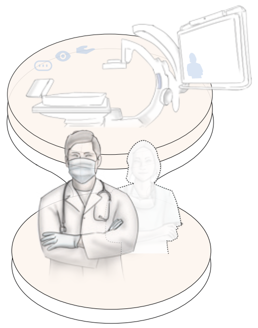
Optimization of communication
Aligning stakeholders and improving workflow through technology

In the second horizon a situation is described in which the connection between human and technology has got even stronger. Therefore, it allows for optimized alignment of stakeholders in the context. Most inefficiencies are prevented and everyone in the cathlab actively participates when needed in a more optimal workflow. Additionally, some of the indirect HCI bottlenecks are minimized through new innovations and accurate alignment of human and technology.

H3

Towards an autonomous cathlab
Optimization of workflow through merging innovations with teamwork

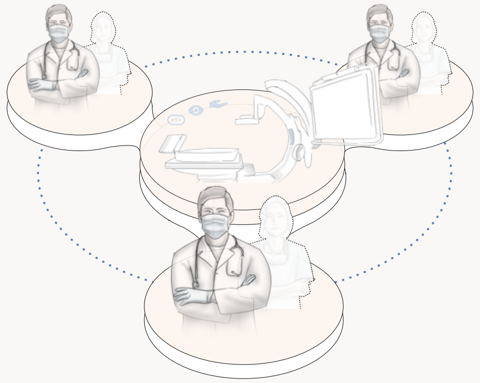
In the last horizon the team's connection between human and technology is so strong that the doctor feels in total control without the loss of any time. Several innovative ideas merge together into an optimized workflow that excludes the need for assistants. Almost all indirect HCI are prevented with the implementation of the concepts mentioned.



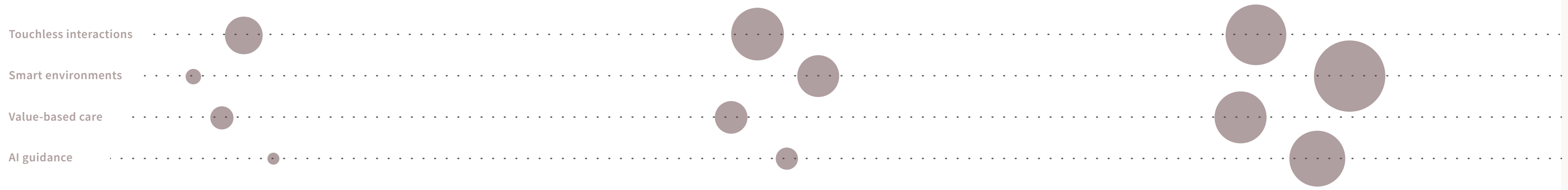
FV

Future vision

"The role of IGT develops towards solving patient pathologies by an aligned medical team, together with significant technological support of multiple smart systems. An optimized, integrated and efficient workflow that is supported by touchless interaction solutions will contribute to value-based care that is provided within the context of IGT."



Healthcare landscape



Design implications

Estimated value

H1

Horizon specific executive performance value	28
Cumulative executive performance value	28

35% *At the end of this horizon, it is assumed that **35% of the improvement target** can be accomplished, resulting in an improved workflow efficiency with a decrease in procedure duration of **4-5 minutes**.*

H2

Horizon specific executive performance value	33
Cumulative executive performance value	61

75% *At the end of this horizon, it is assumed that **75% of the improvement target** can be accomplished, resulting in an improved workflow efficiency with an additional decrease in procedure duration of **5-6 minutes**.*

H3

Horizon specific executive performance value	18
Cumulative executive performance value	79

100% *At the end of this horizon, it is assumed that **100% of the improvement target** can be accomplished, resulting in an improved workflow efficiency with an additional decrease in procedure duration of **3-4 minutes**.*

FV

Estimated improvement target

After implementing all considered concepts
Total executive performance value **79**

The standard procedure timeis aimed to **decrease to 85% of the original procedure time**. Considering an average duration of a PCI procedure being 90 minutes, this results in an average procedure duration of 77 minutes.

Service porpositions

H1
- E-learning update
- Training labs
- Noise-cancelling

H2
- E-learning update
- Training lab update
- Touchless UI workshop
- AR/VR experience centre

H3
- E-learning update
- Training lab update

07 CONCLUSION

In this chapter, several chapters are included in the report to make it a holistic and academic project. A conclusion is given to answer the research questions. The discussion touches upon the relevance of the research within this academic context. The recommendations go into valuable future research propositions. The limitations of this research are presented, and the way these are minimized is explained. At the end, a personal reflection is provided to address the learning objectives and development of myself during this project. Therefore, this chapter touches upon all topics to make this strategic design project complete.

07 - 1 **Conclusion**

In this chapter, the sub-questions and research question defined in chapters 02-3 are answered. These answers are based on the knowledge gained from research and assessment during the course of this thesis. A wholistic answer on the research question (RQ) can be provided by answering the sub-questions first.

SQ - 01 *How can the workflow of the healthcare staff be improved for PCI procedures?*

There is a wide variety of inefficiencies in the workflow of PCI surgery. These time-consuming situations originate from different disruptions of the ideal standard procedure workflow. Sometimes system errors occur during these procedures, leading to delay in actions that are executed. This generally results in more waiting time for the system to keep up. Additionally, since more than half of the interactions happening during an IGT procedure are based on communication, miscommunications are a common and significant problem. It leads towards inefficiencies, error-prone situations and sometimes frustration with the rest of the healthcare staff. Especially since the doctor does not have control over the full procedure. This limitation is mainly caused by the doctor having his hands unavailable or sterility guidelines to prevent infections. This way, the doctor often has to request one of his staff members to execute a task. This is a error-prone workaround that is time-consuming and fully reliant on the clarity of the order, the established teamwork alignment, and the experience of the supporting staff members. Therefore, the doctor is unquestionably reliant on its healthcare staff. Inexperienced staff can also decrease efficiency since they are not well-aligned with the rest of the medical team. As a result, miscommunications happen more often, and they are not properly involved in the intended teamwork system. When these inefficiencies can be minimized, less time is necessary for the required actions, the experience and the workflow of the healthcare staff are improved.

SQ - 02 *How can touchless UI solutions optimally be combined and applied to provide solutions?*

When specific use-cases are identified in which touchless interaction solutions like voice control, gesture sensing and eye-gaze tracking can be used or combined to maximize efficiency, touchless UI provides valuable solutions. By combining these technologies, very natural interaction styles can be achieved. These are easier to implement into the workflow and to use for doctors. In any case, these design implications ought to improve standard procedure workflow. Their value should immediately be noticeable. Additionally, these implementations should not raise new complexities regarding accuracy, reliability and usability. These concepts would allow doctors to have full control over necessary interactions and facilitate improved procedure workflow in the ideal situation. Minimizing the situations in which they rely on their staff and have to work around problems they face in a time-consuming manner.

SQ - 03 *How can the healthcare staff be supported in their interactions?*

It is very important to consider the end-users regarding their needs, wishes and values for implementing new interaction technologies. It is important to consider what doctors are already familiar with and will be familiar with within the upcoming years. Therefore, design guidelines are established in chapter 04-3 to assess the concepts that will be implemented over time. For the full design guideline assessment, see Appendix L. The most important assessed requirements are the defined value drivers for the interaction of novel UI techniques: reliable interaction, accurate interaction, natural and seamless interaction and simple interactions. The proposed design implications meet these requirements to a sufficient quantity. This way, the doctors' needs and wishes are considered, and they are supported in their interactions.

SQ - 04 *How can these design solutions, based on PCI-procedures, be translated towards every medical suite in IGT?*

During the validation session with Atul Gupta MD., he addressed: “This strategy and these concepts would definitely be fully transportable to every one of the IGT suites.”. Since all functionalities of these concepts are used in every other procedure happening in IGT, their value is expected to be very high for every suite. Maybe some concepts would have more value in other suites than other concepts. This is caused by the occurrence of certain actions happening more often in specific procedures. A more extensive transferability strategy can be executed as a recommendation for future research.

SQ - 05 *How are barriers minimized for doctors in the cath lab, to actually use and adopt these technologies?*

The functionalities that these concepts offer are really valuable on their own. However, these implications can't simply be implemented, expecting that doctors will use them on their own initiative. They should come together in an implementation strategy. When they are introduced to the market one by one, doctors are able to get familiar with integrating these technologies in their existing workflow. This way, they get used to touchless interactions, which progressively increases the complexity of functionality and interaction styles. However, to make this implementation more seamless, several service propositions are provided in this project. Services like e-learnings, training labs, touchless UI workshops and experience centres are introduced in chapter 05-4 to smoothen the habituation of these concepts. As a result, the usability and adaptability barriers are minimized for doctors in the cath lab.

RQ *How can the healthcare staff be supported with touchless interaction solutions, during PCI procedures in IGT, to improve workflow?*

Combining the research results with the knowledge gained in this project, it can be concluded that doctors are supported during PCI procedures in IGT through implementing the proposed touchless interaction solutions. When aligning the roadmap with Philips' strategy, it can also be concluded that these concepts are aimed to deliver improved workflow outcomes regarding a decrease in duration of 13 minutes on average. This estimated improvement claim is achieved by minimizing the occurrence of mistakes and inefficient situations. Since the concepts that are considered in this design project address the most urgent bottlenecks in current procedures, significant progress is made regarding an improved workflow. These urgent and time-consuming bottlenecks are considered situations in which miscommunications and errors happen, leading to repetitions, frustration, and staff reliability for tedious actions. Those situations are excluded by allowing the doctor to have more direct interactional control for increased efficiency and decreased reliability. As a result, the time will be minimized by 4/5 minutes – 5/6 minutes – 3-4 minutes for horizon 1 - 2 - 3, respectively. This progressively transitions towards a future vision in which many more improvements can be realised through AR and VR.

“This project is very nicely done! I am excited to see this strategy turn into real life soon.”

– Atul Gupta, MD - Chief Medical Officer, IGT – Philips

07 - 2 **Discussion**

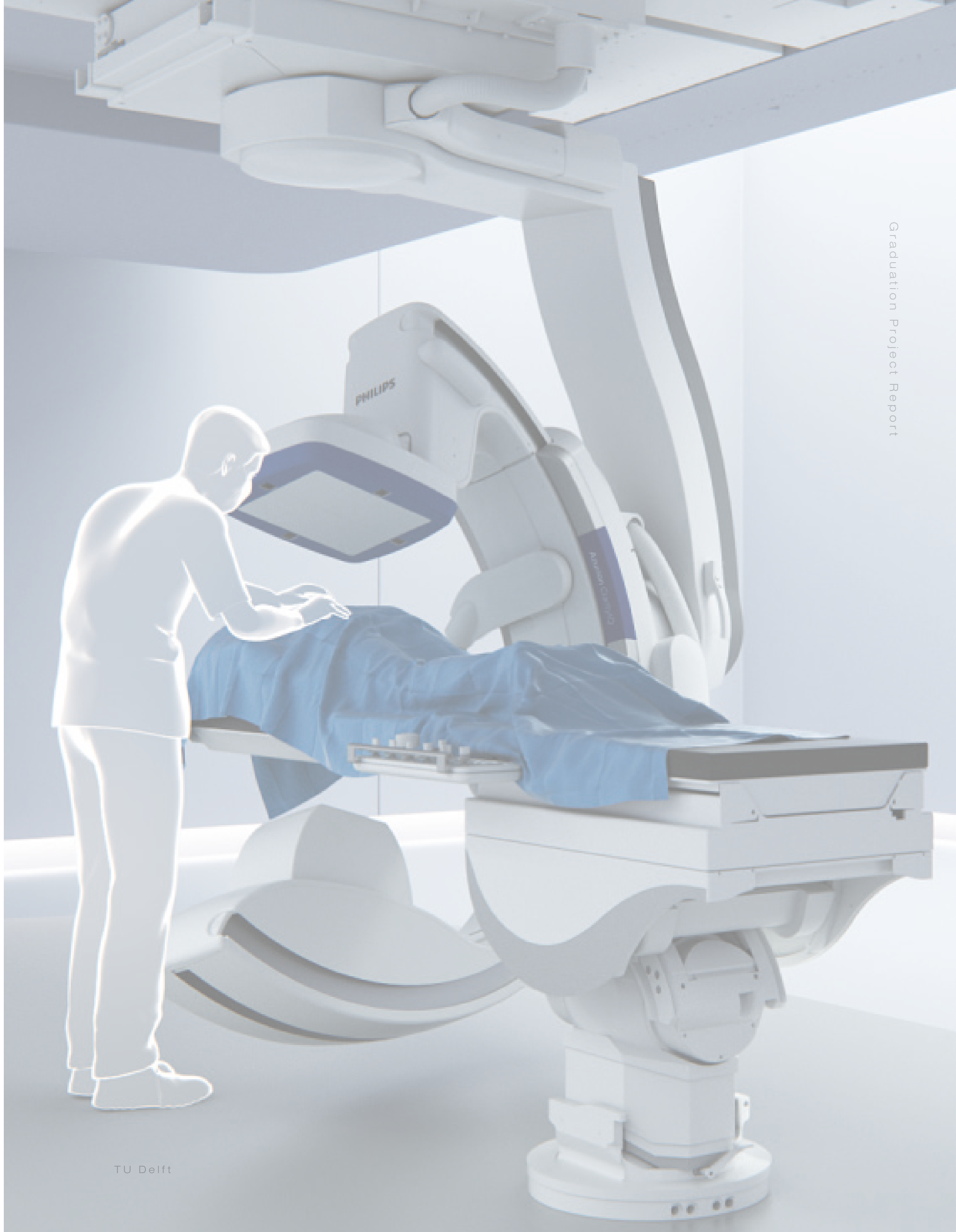
In this chapter, project outcomes are discussed and the relevance of this research project in the context of healthcare is addressed. In order to do so, we will look back at the results and concepts from this research and compare them with initial findings from the literature study in order to assess the contribution of this master thesis.

The most striking result that emerged from this thesis is that specific touchless interaction concepts can be valuable to overcome bottlenecks and inefficiencies that arise in procedures in IGT, resulting in an improved workflow. Providing improved technological infrastructure to minimize miscommunication and dependency on healthcare staff, and improve teamwork alignment and performance of HCI. These problematic sources of inefficiencies resulting from the interaction analysis, are recognized in previous studies of Hübler et al. (2014), Benzko et al. (2016), Wong et al. (2009), Lingard et al. (2004) and Gillespie, Chaboyer and Fairweather (2012). The relevance for improving these inefficiencies is related to the quadruple aim since it entails optimization of healthcare system performance. This aligns with the studies of Arnetz et al. (2020) and Bodenheimer & Sinsky (2014) in which the quadruple aim is explored to assess the enhancement of healthcare efficiency. Therefore, the foundation of this design project is validated and in line with earlier studies addressed in this discussion.

This design thesis adds value to the healthcare market and the opportunity provider, Philips Experience Design. The project pursues contribution to meaningful innovation within this specified healthcare niche to improve the care that is provided and reduce the costs for hospitals and patients. This project indicates the importance of continuously looking for valuable improvements in providing healthcare for both healthcare organizations and health technology providers. Philips Experience Design plays an essential role in delivering improved and optimal care. The future scenarios, concepts, service propositions and the roadmap provide inspiration and elaboration based on a carefully established research and analysis.

Fundamentally, through this thesis I am providing Philips with a strategy that can serve as guidance and argumentation for future implementations. It can be used to grow Philips' market share in IGT, staying ahead of the competition, and maintaining relevance for the upcoming years of development. By proposing concepts that are not only based on new technological possibilities, but also on input from the industry, it provides high value for the end-users.

This research is also aimed to spark research for Strategic Product Design students (with a specialization in Medisign) and professors at the faculty of IDE that are looking for relevant research and have interest in strategic design innovation for healthcare.



07 - 3 **Recommendations**

Several future research directions and recommendations are introduced in this chapter to improve and anchor the quality and relevance of this thesis. As described in the previous chapter, this thesis has relevance for an implementation strategy on a conceptual level. In future projects, valuable additions and new research possibilities can be established from this strategic foundation.

A valuable addition to this research would be to **extensively dive into the values and benefits for Philips** when this implementation strategy is applied. Specifying and aligning these benefits and values of implementing these concepts with Philips' strategy would lead to more depth, resulting in a finely tuned project that is even more organizationally embedded within the company of Philips.

Another addition to this project could be the **extension and strengthening of the explorative interactional analysis**. By observing more procedures (possibly live), a more thorough analysis could lead to a thicker understanding of the workflow and inefficiencies of specific procedures. Maybe a distinction between other medical suites of IGT can be concluded to validate the transferability to other interventions.

Additionally, during the literature research, interaction analysis, interviews and brainstorm sessions, many anchor points for **new research possibilities** emerged. In general, these research topics are marginally outside of my design scope. However, they would definitely be an extension of this thesis. **(1)** An additional research direction would be to dive into training methods for these concepts and technologies. From multiple sources in the research done, it can be concluded that this is an essential element for successfully implementing novel UI technologies in IGT. **(2)** Another possible direction is to design a strategy to minimize differences in teamwork, workflow and use of the IGT systems in hospitals (inter)nationally. From the interviews, it could be concluded that healthcare staff doing these procedures always have their own way of working. However, if this is standardized, a lot of business processes (like training) can be more efficient. **(3)** Prototyping, developing and testing the concepts presented in this thesis would also be an interesting research assignment. Since Philips is already planning on doing some user tests with 'touchless UI-based' prototypes, it would be in line with the company's activities and interests. **(4)** Within this thesis, the future vision of the roadmap results in a connection towards augmented reality and virtual reality. However, the actual transition between using touchless UI in 2D towards using touchless UI in 3D (in augmented reality and virtual reality) is not addressed. Designing a strategy for this transition would be desirable for a seamless, innovative implementation process of touchless UI.

07 - 4 **Limitations**

In order to deliver a holistic research project, it is important to address the possible limitations of the project. Several aspects of this project could have been elaborated to a larger extend, however, it was not possible due to complex circumstances related to sensitive data, available content and contacts, biases, etcetera. Several parts of this project are addressed in this chapter. For each component, it is described how it is aggrieved but also how this limitation is minimized.

Interactional analysis

In the explorative interaction analysis, three complete procedures are considered. Basically, no more easy-accessible recordings were available at the moment. This occurrence is minimized by detecting and highlighting similarities and differences within observed interactions through colour-coded post-its. This way, an averaged overview of a PCI procedure is still a reliable foundation to establish a valuable analysis.

On the other hand, the source of information was facilitated by observations of recordings. These recordings are (in some cases) posted publicly. Therefore, some type of selection and/or editing has occurred to these files. This could result in a minimal amount of mistakes happening during the observed procedures. Additionally, the doctors are conscious of themselves being filmed and audio-recorded. This could influence the behaviour shown in these videos. A comprehensive and versatile view could be obtained by selecting particular videos with different doctors from various countries and distant moments. Avoiding a specific focus on one particular doctor showing identical behaviour and executing the same procedure repeatedly.

Research method

During the research into gaining a deeper understanding of the end-user, four interviews were conducted. My aim was to do six full interviews with doctors that are/were active within the context of IGT. Contacting these potential participants was sometimes cumbersome and limited due to privacy restrictions. Through snowball sampling, only four interviews were conducted with appropriate interviewees. However, since these semi-structured interviews were combined with an interactive workshop, a lot of qualitative data could still be gathered.

The interviews held with the doctors that were familiar with IGT procedures were all non-active doctors anymore. Therefore, it could be the case that they were not up-to-date with the latest technologies and functionalities that the Azurion-system has. Nevertheless, an overall understanding and almost all functionalities are still recognized. For this reason, very similar problems and opportunities were identified. This resulted in similar outcomes for future implementation values for novel interactions in the cath lab.

Brainstorming and concepts

During the brainstorming session, 12 people from Philips were included that were familiar with IGT. Since all stakeholders were from Philips internally, there is a chance that some biased ideas resulted from the brainstorm. Unfortunately, we could not include external ‘unbiased’ stakeholders because of sensitive information and insufficient background knowledge. However, all participants were from different project teams and had varying backgrounds and perspectives on this medical field. Therefore, by combining these different viewpoints, biases in ideation are minimized. The assessment of the most important value drivers from the established concepts was done by myself. I would have preferred to have done this with the stakeholders that I interviewed. However, during this graduation project, I gained much expertise in the use of devices and systems in the context of IGT. Therefore, it is expected that this initial assessment of the concepts is still valid. Additionally, the concepts are asses during the validation with Atul Gupta, who confirmed my expectations.

Validation

The validation session was relatively short because of the busy schedule of Atul Gupta. Therefore, I could only assess and validate the most important results for the concepts and the roadmap. However, by preparing the meeting very well and applying a tight schedule and filtering the most important goals for the meeting, valuable insights were still derived within a short timeframe.

Roadmap

In the roadmap, an estimated improvement claim is established for the future vision. This is an expected indication made by myself to be able to say something about the value of this roadmap for IGT. An assumed claim is made as good as possible by taking into account tedious and complex innovation possibilities in the healthcare environment. In upcoming research, this claim can be validated and extended to provide more structural insights.

Additionally, the developments of the concepts over time are not taken into account in the business value of the roadmap. Chapter 05-1 introduces concepts, and a description is provided on how these concepts could develop over time. Possible improvements in quality and extensions of the concepts are not considered in the calculated executive performance and, therefore, not in the roadmap.

07 - 5 Personal reflection

At the end of this project, it is appropriate to write a personal reflection of this project to address what I have learned and developed in the past 20 weeks. So, looking back at this project I can see that I have developed in both professional and personal ways. Building on to the foundation of knowledge and experience that I have gained in the past six years, certain personal goals are definitely achieved. I am very grateful for the position in which Philips (and my coach) gave me the freedom and grips to develop myself in a professional environment. It was an environment in which I was not afraid to make mistakes and was open for feedback to improve myself and my project. In this reflection, I will look back at the initial personal learning objectives, that are defined in the graduation proposal. Also, I will address several other learning objectives that were not defined at the start of this graduation project.

Personal learning objectives

During the initial phase of this graduation project, I wrote down some learning objectives that I was aiming to achieve in order for me to set development goals. These objectives are discussed and reflected on below.

01 Understanding of technologies and the implementation into a complex medical design context

“I want to understand how combinations of UI techniques can be implemented in practice. During this project I want to get more familiar with a step further: implementation in practice. Especially with new technologies like these.”

This learning objective is definitely achieved. I gained a very deep understanding of all touchless UI technologies and how they are supposed to be used in design. By reading a lot of literature, watching videos, doing AR experiments myself and talking to people about it, a thick understanding is established. Additionally, for the most part, I understand the complex context of IGT very well. Considering the level of design integration that this project is scoped on. Integrating new innovations in contexts like takes a lot of time, is very complex and consideration of the end-users.

02 Strategically substantiation of a roadmap

“I want to obtain a deeper understanding on how to make such a roadmap strategically substantiated. This will help me make this project more valuable. Additionally, it will help me in the future when I am working on similar projects in practice.”

The learning objective mentioned above is something that has always been difficult. When is something strategic? Well, for this graduation project I have definitely gained experience in establishing strategically substantiated deliverables. For example, taking into account Philips and aligning the roadmap to their strategy, (future) needs, and goals in order to make a business case, made this roadmap strategically substantiated.

03 Operating in a professional company

“I want to understand how these innovation projects are setup in a big professional company. I have always been interested in the implementation of innovative technologies. Understanding how this works in a corporate structure, will be insightful.”

Philips providing me with the business infrastructure, company office and the nice colleagues has definitely given me initial insights and experience in ways to operate in a professional company. Managing projects, setting-up meetings, organizing brainstorm sessions, company structure, etcetera are examples of things that gave me in idea on how innovation projects are set up in Philips.

04 Communicating my project

“I want to learn to communicate my design process in a clear way for corporate (non-)designers.”

The personal learning objective above is something that I have learned quite well during the course of this project. By talking to a lot of different stakeholders and asking them for feedback, gave me a wide range of listeners. I adjusted my text and presentations to the audience. This gave me more confidence in my project and also awareness of the gaps within this project.

05 Reflection and making design decisions

“I want to learn how to reflect and make clear, deliberate decisions in order to achieve my initial goal. This is all about good project management. This can lead to a better results and clear communication. It will result in me being confident in the design decisions that I make.“

The objective mentioned above has always been a topic of attention for myself. During the course of this project, I think this improved quite a bit. I was able to deal with critical feedback, reflect on my own process, make adjustments to my design process and make deliberate design decisions that increased the quality of my project. Therefore, I gained a lot of confidence in myself regarding managing my own project. However, I do think that this will always be something for me to keep improving.

Other learnings

During the course of this project I used Miro for everything. This programme allowed me to manage my project extremely effective. Making day-to-day planning, making a structure for the report, doing analyses, conducting interviews, analysing results, ideation sessions, setting up the roadmap, etcetera are examples of what Miro enabled me to do. The visual representation that it provides works really well for me. I think I can call myself a Miro expert at this point! Due to that programme, I was able to be really consistent and conscious about my planning. I think that this is also the reason that I was able to execute this project so efficiently. Scheduling and preparing meetings with a planning made me confident in managing and leading that meeting towards a successful conclusion.

Because of the multiple presentation that I had to give at Philips, I think that I got better at doing this as well. I am aware of elements for improvement regarding presentation skills, however, I think I gained a lot of experience by doing it so often.

In general, I must say that one of the biggest learnings of this graduation project was my professional confidence. Graduation in times of a pandemic is sometimes difficult, especially when you are doing an individual project. Before starting this opportunity, I was quite insecure about my capabilities as a student, as a colleague, as a manager of myself, and as a designer. However, this project really helped me understand what I am good at, that I can trust myself with it, where my value lies, and so on. Therefore, I am very grateful for the supervision that I got by always giving me the feeling of trust that you have in me and my project. Thank you.

Kind regards,
Victor Wijn

08 REFERENCES

A

Arnetz, B.B., Goetz, C.M., Arnetz, J.E., Sudan, S., vanSchagen, J., Piersma, K., Reyelts, F. (2020). Enhancing healthcare efficiency to achieve the Quadruple Aim: an exploratory study. BMC Research Notes (2020), 13(1). doi: 10.1186/s13104-020-05199-8

B

Backhaus, C. (2010). Usability-Engineering in der Medizintechnik: Grundlagen-Methoden-Beispiele. Heidelber, Germany: Springer 2010. doi: 10.1007/978-3-642-00511-4

Bagnara, S., Tartaglia, R., Albolino, S., Alexander, T., Fujita, Y. (2018) Proceedings of the 20th Congress of the International Ergonomics Association (IEA 2018). IEA 2018. Advances in Intelligent Systems and Computing, vol 822. Springer, Cham.

Balter, S., Simon, D., Itkin, M., Granada, J.F., Melman, H., Dangas, G. (2016). Significant radiation reduction in interventional fluoroscopy using a novel eye controlled movable region of interest. Medical Physics (2016). doi: 10.1118/1.4941955

Benzko, J., Krause, L., Janβ, A., Marschollek, B., Merz, P., Dell'Anna, J., Radermacher, K. (2016). Modular user interface design for integrated surgical workplaces. Biomedizinische Technik, (2016), 61(2). doi: 10.1515/bmt-2014-0125

Berwick, D. M., Nolan, T. W., & Whittington, J. (2008). The triple aim: care, health, and cost. Health Affairs (2008) 27(3), 759-769. doi: 10.1377/hlthaff.27.3.759

Bigdelou, A., Schwarz, L.A., Navab, N. (2012). An adaptive solution for intra-operative gesture-based human-machine interaction. International Conference on Intelligent User Interfaces, Proceedings UI (2012). doi: 10.1145/2166966.2166981

Bodenheimer, T., & Sinsky, C. (2014). From triple to quadruple aim: care of the patient requires care of the provider. Annals of Family Medicine, (2014), 12(6), 573-576. doi: 10.1370/afm.1713

C

Chao, C., Tan, J., Castillo, E.M., Zawaideh, M., Roberts, A.C., Kinney, T.B. (2014). Comparative efficacy of new interafces for intra-procedural imaging review: The Microsoft Kinect, Hillcrest Labs Loop Pointer, and the Apple iPad. Journal of Digital Imaging (2014). doi: 10.1007/s10278-014-9687-y

Cronin, S., Doherty, G. (2019). Touchless computer interfaces in hospitals: a review. Healthcare Informatics Journal 2019, Vol. 25(4) 1325-1342. doi: 10.1177/1460458217748342

D

David-John, B., Peacock, C. E., Zhang, T., Murdison, T. S., Benko, H., Jonker, T. R. (2021). Towards gaze-based prediction of the intent to interact in virtual reality. In ETRA '21: 2021 Symposium on Eye Tracking Research and Applications (ETRA '21 Short Papers), May 25–27, 2021, Virtual Event, Germany. ACM, New York, NY, USA, 7 pages. doi: 10.1145/3448018.3458008

Design Council. (2005). What is the framework for innovation? Design Council's evolved double diamond. Retrieved from: https://www.designcouncil.org.uk/news-opinion/what-framework-innovation-design-councils-evolved-double-diamond

E

Enisa. (2016). Smart hospitals: Security and Resilience for Smart Health Service and Infrastructures. Retrieved from: https://www.enisa.europa.eu/publications/cyber-security-and-resilience-for-smart-hospitals

F

Fairbanks, R.J., Caplan, S. (2004). Poor interface design and lack of usability testing facilitate medical error. Jt Comm J Qual Saf 2004; 30: 579-584. doi: 10.1016/S1549-3741(04)30068-7

Faro, A., Giordano, D., Spampinato, C., De Tommaso, D., Ullo, S. (2010). An interactive interface for remote administration of clinical tests based on eye tracking. Eye Tracking Research and Applications Symposium (ETRA) (2010). doi: 10.1145/1743666.1743683

Fotouhi, J., Mehrfard, A., Song, T., Johnson M.D., A., Osgood M.D., G., Unberath, M., Armand, M., Navab, N. (2020). Spatiotemporal-aware augmented reality: redefining HCI in Image-guided therapy. arXiv: 2003.02260v1

G

Gallo, L. (2013). A study on the degrees of freedom in touchless interaction. In: Proceedings of the SIGGRAPH Asia 2013 technical briefs, Hong Kong, China. New York: ACM. doi: 10.1145/2542355.2542390

Gillespie, B.M., Chaboyer, W., Fairweather, N. (2012). Interruptions and miscommunications in Surgery: an observational study. AORN Journal, (2012), 576-590, 95(5). doi: 10.1016/j.aorn.2012.02.012

Grand View Research (2021). Image-guided Therapy Systems Market Size Worth 5.8 billion dollar by 2028. Retrieved from: https://www.grandviewresearch.com/press-release/global-image-guided-therapy-systems-market

Greenspun, H. (M.D.). (2020). 5 trends that will shape healthcare in 2021. MedCity. Retrieved from: https://medcitynews.com/2020/12/5-trends-that-will-shape-healthcare-in-2021/

H

Healthie. (2021). 5 Healthcare Trends for 2021. Retrieved from: https://www.gethealthie.com/blog/health-wellness-trends-2021

Helmberger, T., Martí-Bonmatí, L., Pereira, P., Gillams, A., Martínez, J., Lammer, J., Malagari, K., Gangi, A., de Baere, T., Adam, E. J., Rasch, C., Budach, V., Reekers, J. A. (2013) Radiologists' leading position in image-guided therapy. Insights Imaging (2013) 4:1–7. doi: 10.1007/s13244-012-0213-9

Hölscher, U.M., Heidecke, C.D. (2012). Defizite in der Patientensicherheit. Deut Zeitsch Klin Forschung 2012; ¾: 102-105. Retrieved from: https://www.hb.fh-muenster.de/opus4/frontdoor/deliver/index/docId/552/file/DZKF_Defizite_in_der_Patientensicherheit_v03.pdf

Hübler, A., Hansen, C., Beuing, O., Skalej, M., Preim, B. (2014). Workflow analysis for interventional Neuroradiology using Frequent pattern mining. CURAC 2014. Corpus ID: 11264678

J

Jacob, M.G., Wachs, J.P., Packer, R.A. (2013). Hand-gesture-based sterile interface for the operating room using contextual cues for the navigation of radiological images. Journal of the American Medical Informatics Association (2013). doi: 10.1136/amiajnl-2012-001212

Jewell, t. (2018). What is Minimally Invasive Surgery?. Retrieved from: https://www.healthline.com/health/minimally-invasive-surgery .

Johnson, R., O'Hara, K., Sellen, A., Cousins, C., Criminisi, A. (2011). Exploring the potential for Touchless interaction in Image-Guided Interventional Radiology. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (Vancouver, Canada, May 7–12). ACM Press, New York, 2011. doi: 10.1145/1978942.1979436

L

Latif, S., Qadir, J., Qayyum, A., Usama, M., Younis, S. (2021). Speech technology for Healthcare: Opportunities, Challenges and State-of-the-art. IEEE Rev Biomed Eng. 2021;14:342-356. doi: 10.1109/RBME.2020.3006860.

Latif, S., Rana, R., Qadir, J., Ali, A., Imran, M.A., Younis, M.S. (2017) Mobile health in the developing world: Review of literature and lessons from a case study. IEEE Access (2017). doi: 10.1109/ACCESS.2017.2710800

Ligtvoet, F. (2019). Ziekenhuizen speelden grote rol in eigen personeelstekort. NOS. Retrieved from: https://nos.nl/nieuwsuur/artikel/2277973-ziekenhuizen-speelden-grote-rol-in-eigen-personeelstekort

Lingard, L., Espin, S., Whyte, S., Regehr, G., Baker, G.R., Reznick, R., Bohnen, J., Orser, B., Doran, D., Grober, E. (2004). Communication failures in the operating room: an observational classification of recurrent types and effects. Qual Saf Health Care 2004; 13: 330-334. doi: 10.1136/qshc.2003.008425

M

Meng, M.A., Fallavollita, P., Habert, S., Weidert, S., Navab, N. (2016) Device- and system-independent personal touchless user interface for operating rooms: One personal UI to control all displays in an operating room. International Journal of Computer Assisted Radiology and Surgery (2016). doi: 10.1007/s11548-016-1375-6

Mentis, H., O'Hara, K., Sellen, A., and Trivedi, R. (2012) Interaction proxemics and image use in neurosurgery. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (Austin, TX, May 5–10). ACM Press, New York, 2012, 927–936. doi: 10.1145/2207676.2208536

van Meurs, B. (2019). Five innovations that are shaping the future of image-guided therapy. Philips. Retrieved from: https://www.philips.com/a-w/about/news/archive/standard/news/press/2021/20210420-five-year-patient-level-meta-analysis-of-illumenate-eu-rct-and-pivotal-study-results-confirms-safety-profile-of-philips-stellarex-035-low-dose-drug-coated-balloon.html

Mewes, A., Hensen, B., Wacker, F., Hansen, C. (2017) Touchless interaction with software in interventional radiology and surgery: a systematic literature review. International Journal of Computer Assisted Radiology and Surgery, (2017), 12(2). doi: 10.1007/s11548-016-1480-6

Meyer, M., Levine, W. C., Egan, M. T., Cohen, B. J., Spitz, G., Garcia, P., Chueh, H., Sandberg W. S. (2007) A computerized perioperative data integration and display system. International Journal of Computer Assisted Radiology and Surgery 2(3-4), pp. 191-202. doi: 10.1007/s11548-007-0126-0

O

O'Hara, K., Gonzalez, G., Sellen, A., Penney, G., Varnavas, A., Mentis, H., Criminisi, A., Corish, R., Rouncefield, M., Dastur, N., Carrell, T. (2014) Touchless Interaction in Surgery. Communications of the ACM, (2014), 57(1). doi: 10.1145/2541883.2541899

Osvalder, A.L., Bligard, L.O. (2007). Usability and ergonomics in medical equipment. In: Proceedings of the 39th Nordic ergonomics society conference, October 1-3 2007, Lyeskil, Sweden 2007. Retrieved from: http://www.arbetsliv.eu/nes2007/papers/A121_Osvalder.pdf

P

Philips (2017a). Growing our leadership in Image-Guided Therapy. Retrieved from: https://www.philips.com/static/qr/2017/cmd/2017/07_Growing_our_leadership_in_Image-Guided_Therapy.pdf

Philips (2017b). IVUS 3.x Workflow Analysis Report Out presentation.

Philips (2017c). User study to evaluate new workflow approach. Retrieved from: https://www.usa.philips.com/c-dam/b2bhc/master/landing-pages/azurion/philips-azurion-simulation-study-whitepaper.pdf

Philips. (2019a). Bedrijfsprofiel. Retrieved from https://www.philips.nl/a-w/about-philips/bedrijfsprofiel.html

Philips. (2019b). Our strategic Focus. Retrieved from https://www.philips.com/a-w/about/company/our-strategy/our-strategic-focus.html

Philips. (2020). Trends report.

Philips Conversational UI. (2017). Conversational UI Report out presentation.

Philips Gaze enhanced UX. (2020). Gaze enhanced UX Report out presentation.

Philips Gesture Control. (N.D.). Gesture Control Report out presentation.

Popken, L. (2020). Waarom de zorgpremies voor 2021 flink omhoog gaan: 'het wordt een onzeker jaar'. Trouw. Retrieved from: https://www.trouw.nl/zorg/waarom-de-zorgpremies-voor-2021-flink-omhoog-gaan-het-wordt-een-onzeker-jaar~bcde61ac/?referrer=https%3A%2F%2Fwww.google.com%2F

PwC. (2021). Megatrends, Demographic changes. Retrieved from: https://www.pwc.nl/en/topics/megatrends/demographic-changes.html

Schröder, S., Loftfield, N., Langmann, B., Frank, K., Reithmeier, E. (2014). Contactless operating table control based on 3D image processing. 2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBC 2014 (2014). doi: 10.1109/EMBC.2014.6943610

Shanafelt, T.D., West, C.P., Sinsky, C., Trockel, M., Tutty, M., Satele, D.V., Carlasare, L.E., Dyrbye, L.N. (2019) Changes in Burnout and Satisfaction with Work-life integration in Physicians and the General US Working population between 2011 and 2017. Mayo Clinic Proceedings (2019). doi: 10.1016/j.mayocp.2018.10.023

Siddaiah-Subramanya, M., Tiang, K., Nyandowe, M. (2017) A New Era of Minimally Invasive Surgery: Progress and Development of Major Technical Innovations in General Surgery Over the Last Decade. The Surgery Journal, (2017), 03(04). doi: 10.1055/s-0037-1608651

Simonse, L. (2017). Design Roadmapping. Amsterdam: BIS Publishers.

Smith, M., Saunders, R., Stuckhardt, L., McGinnis, M. (2013). Best Care at Lower Cost: The Path to Continuously Learning Health Care in America. Washington (DC): National Academies Press (US); 2013 May 10. PMID: 24901184. doi: 10.17226/13444

Soehngen, E., Rahmah, N. N., Kakizawa, Y., Horiuchi, T., Fujii, Y., Kiuchi, T., Hongo, K. (2012) Operation-Microscope-Mounted Touch Display Tablet Computer for Intraoperative Imaging Visualization: Technical Note and Comparison with Other Modalities. World Neurosurgery, 77(2), pp. 381-383. doi: 10.1016/j.wneu.2011.06.017

Strickland, M., Tremaine, J., Brigley, G., Law, C. (2013). Using a depth-sensing infrared camera system to access and manipulate medical imaging from within the sterile operating field. Canadian Journal of Surgery (2013). doi: 10.1503/cjs.035311

Trejos, A., Siroen, K., Ward, C.D., Hossain, S., Naish, M.D., Patel, R.V., Schlachta, C.M. (2015). Randomized control trial for evaluation of a hands-free pointer for surgical instruction during laprascopic cholecystectomy. Surgical Endoscopy (2015). doi: 10.1007/s00464-015-4122-0

Wachs, J.P., Stern, H.I., Edan, Y., Gillam, M., Handler, J., Feied, C., Smith, M., (2008). A Gesture-based Tool for Sterile Browsing of Radiology Images. Journal of the American Medical Informatics Association (2008). doi: 10.1197/jamia.m241

Wachs, J.P., Kölsch, M., Stern, H., Edan, Y., et al. (2011). Vision-based hand-gesture applications. Communications of the ACM (2011). doi: 10.1145/1897816.1897838

Wallace, D.S. (2018). The role of speech recognition in clinical documentation. Nuance Commun.. Retrieved from: https://www.hisa.org.au/slides/hic18/wed/SimonWallace.pdf

Wollgast, J., Schrader, A., Mentler, T. (2019). Text Input in Hospital Settings Using IoT Device Ensembles. IEA 2018. Advances in Intelligent Systems and Computing, vol 822. Springer, Cham. doi: 10.1007/978-3-319-96077-7_66

Wollgast, J. (2017). Text Input in Hospital Settings Using IoT Device Ensembles. University of Lübeck (in German). doi: 10.1007/978-3-319-96077-7_66

Wong, D.A., Herndon, J.H. Canale S.T., Brooks, R.L., Hunt, T.R., Epps, H.R., Fountain, S.S., Albanese, S.A., Johanson, N.A.. (2009). Medical errors in orthopaedics results of an AAOS member survey. J Bone Joint Surg Am 2009; 91: 547-557. doi: 10.2106/JBJS.G.01439

World Health Organization. (2018). Ageing and health. Retrieved from: https://www.who.int/news-room/fact-sheets/detail/ageing-and-health