Master thesis
SPD

Pino van de Ven
TU Delft

CHALLENGES IN ADOPTION OF HAPTIC TECHNOLOGY
THE CASE OF SENSEGLOVE

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ACKNOWLEDGEMENT

With the completion of this thesis, I also conclude my period of study in Delft. It has been a time of great learning and personal growth for me as a designer and as an individual.

During my bachelor's degree at the Faculty of Industrial Design, I acquired the fundamental skills of design. These foundational skills, such as understanding the user and knowledge of different design methods, have already proven valuable to me and will continue to benefit me throughout my life. In my master's program, I specialized in the business context of product and service design, a direction I intend to pursue in the future as well. I am immensely grateful to the Delft University of Technology and specifically the Faculty of Industrial Design, along with all its staff, for everything I have had the opportunity to learn. I would also like to express my gratitude to my fellow students, without whom I would not have been able to undergo these developments.

I am incredibly thankful for the completion of this period at SenseGlove. From day one, it felt like a warm bath. The entire team was always willing to assist me with any questions and showed genuine interest in my work. I would like to thank Gijs den Butter for the carpool rides from Amsterdam to Delft, during which I could ask all my questions. Special thanks to David Mullet and Sophie Smith for the amazing week at MWC Barcelona, where I not only gained new insights but also had a lot of fun. And a heartfelt thank you to Anne Hermans for your guidance throughout this process. You were always there to help me with questions and to brainstorm about the project. Even during periods when things were challenging, you remained flexible and helped me stay motivated.

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Lastly, I would like to express my gratitude to my family for their support. Especially my sister Anne, for helping motivate me and successfully bringing this project to its completion.

EXECUTIVE SUMMARY

This thesis report explores the integration of haptic technology in enterprise processes through the case of SenseGlove, a scale-up company based in YesDelft that produces Virtual Reality Gloves. The study aims to identify the potential barriers and requirements for the enterprise's clients to adopt haptic technology and integrate it into their company processes. The research also investigates potential markets for SenseGlove's products, with a particular focus on the online meetings market.

Initially, the researcher intended to design a new use case for SenseGlove products. However, further research revealed that numerous ideas for haptic glove applications already existed. Recognizing the company's vision to enter the consumer market and become the mouse and keyboard of the future, the researcher decided to further investigate what could be a way for SenseGlove to accomplish this. Drawing upon the concept of prosumer products, exemplified by smartphones and 3D printers, the study explored four potential markets, ultimately selecting the online meetings market as the most promising through the application of Blue Ocean Theory.

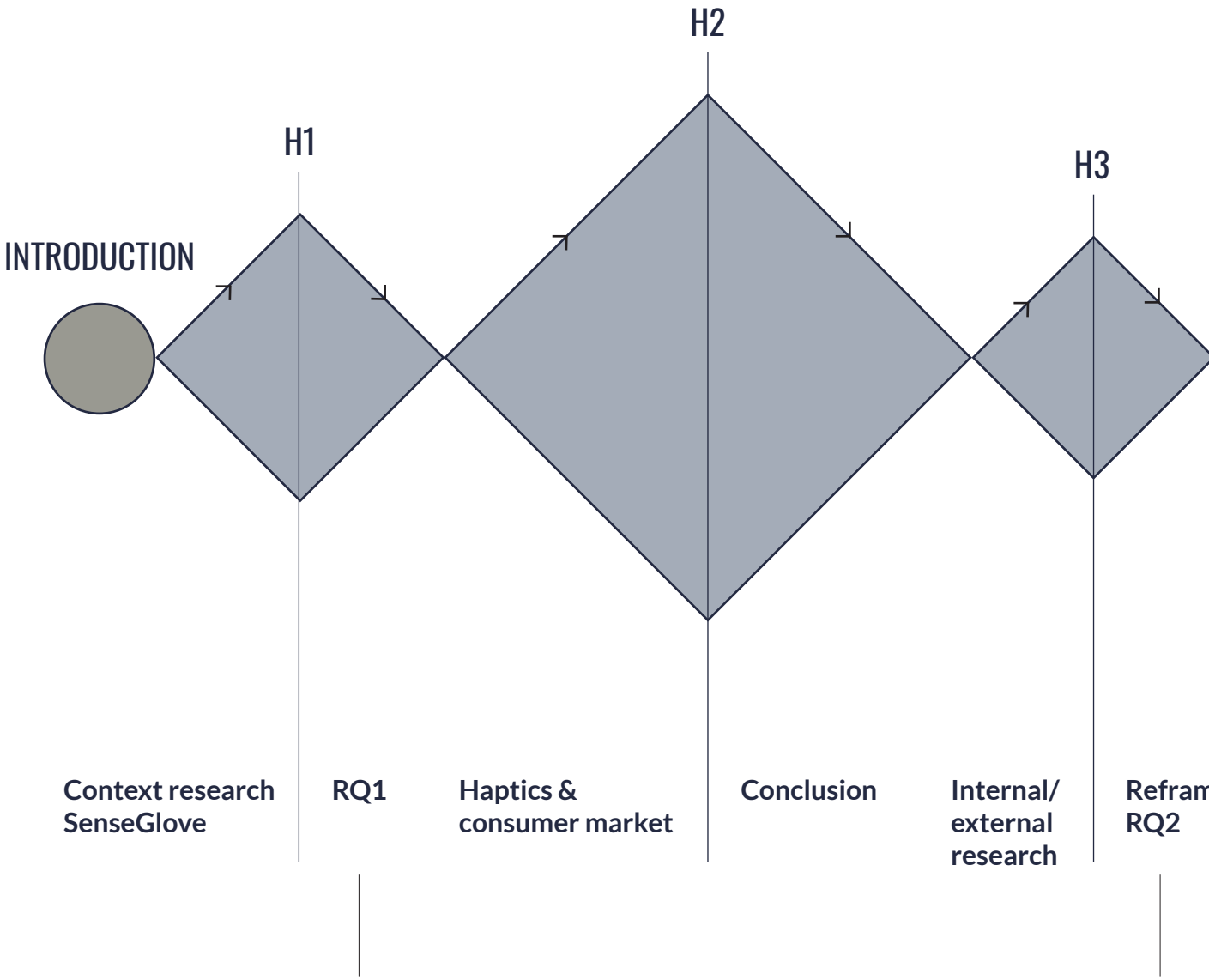
To assess the potential of haptic technology in online meetings, the researcher conducted an interview with a professional experienced in online and offline meetings and performed additional observational research. The findings, combined with an examination of market factors such as price and virtual/augmented reality, implied that it was not currently advisable for SenseGlove to enter the consumer market. The main argument supporting this vision is that peripheral products like haptic technology heavily rely on the development of the AR and VR markets, which have not yet had a breakthrough in the consumer market.

A pivotal aspect of the thesis involved an internal analysis of SenseGlove's Strengths, Weaknesses, Opportunities and Threats , uncovering an important issue: very few, if any, of the current clients integrated SenseGlove's product into their company processes. This discovery led to the formulation of the research question: "What needs to happen for enterprise clients to start integrating haptics in their company processes?" To explore this question, the researcher employed grounded theory, conducting qualitative research through interviews with 15 of SenseGlove's clients. By analyzing these responses a comprehensive list of 15 arguments was created, detailing the necessary product improvements for SenseGlove's clients to embrace their product. These arguments were subsequently clustered into three categories: immersiveness, usability, and costs versus benefits.

The final chapter of the thesis presents strategic recommendations in the form of a future roadmap for SenseGlove. This roadmap consists of three steps; step one focuses on encouraging adoption of the product, step two outlines strategies for establishing SenseGlove as the industry standard in the business-to-business haptics market, and step three explores entering the consumer market with a product specifically tailored for online meetings.

The findings of this thesis provide valuable insights for SenseGlove's future direction and development. By addressing the identified barriers and incorporating the recommended roadmap, SenseGlove can enhance its product offering, increase integration with enterprise clients, and potentially position itself as a leader in the haptic technology market.

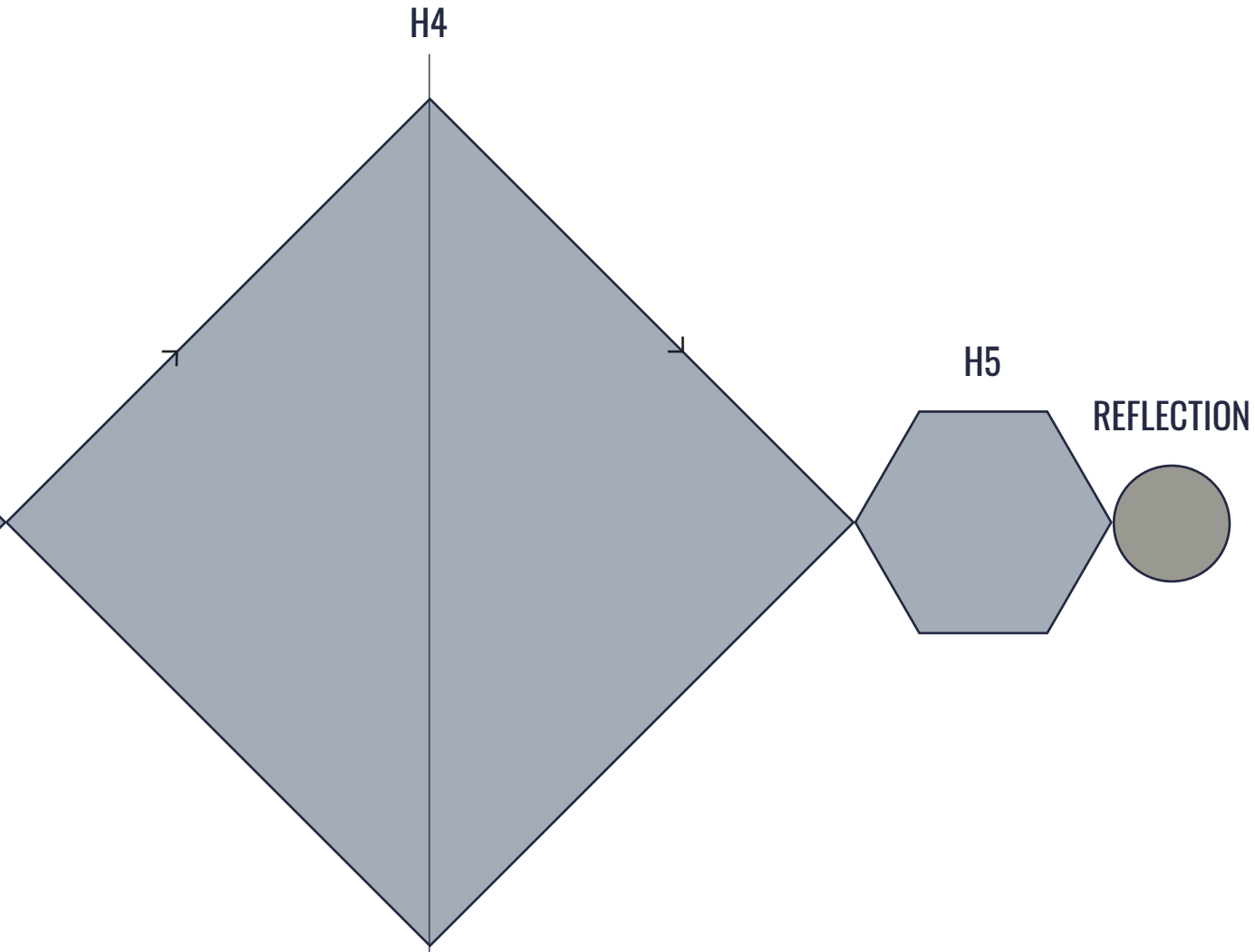
READER GUIDE



RQ1.1: What consumer market should SenseGlove's prosumer product address?

RQ1.2: To what extent is SenseGlove's ambition to enter the consumer market realistic?

RQ 2: What interventions can adoption in their customers' o



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Adoption research
Haptic techology in entreprise markets

Results/conclusion

Immersiveness
Usability
Costs vs benefits

Design/ recommendations
A roadmap for SenseGlove

help SenseGlove to increase
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INTRODUCTION

My choice to pursue a Master's degree in strategic product design was inspired by the observation that while there are countless intriguing ideas out there, only a marginal proportion of them are successfully implemented in society. Whilst nearing the completion of my education at the Technical University of Delft, I hope to be well equipped as a designer to produce concepts that are both innovative and viable. To put this to the test, I wanted to complete my graduation project within the (different) context of an established company.

In October 2019, I was first introduced to SenseGlove. At the time, I was working on a design for children's toys and testing my first prototypes at the children's department of the Delft library. While observing two children playing with my prototypes, I was engaged in a conversation with their father, Niels, who was working for SenseGlove at the time.

This was my first introduction to haptic technology and haptic gloves in particular. As a designer, I found the concept of haptic technology to be incredibly intriguing, and our conversation sparked my enthusiasm for the topic a lot.

Three years later, whilst preparing for my Master's thesis, I thought back of Niels, and reached out to SenseGlove, who kindly invited me to temporarily join their team as a graduate student.

As a strategic product designer, I have learnt to break down and help define an organization's mission, goals and the products and services that align with them. I believe this to be a particularly relevant skill in young organizations like SenseGlove, where the direction may not be entirely clear or change frequently. I feel like SenseGlove stands at the start of a technology that could potentially have a big impact on our society, but before it can, it still needs to make a breakthrough. In the next chapter I will further define this problem, narrow down the scope of my project, and formulate a research question.

01
CONTEXT.

SenseGlove is a scale-up company based in YesDelft. It was founded in 2016 by Johannes Luijten and Gijs den Butter, who started the company out of a graduation project. In 2017, SenseGlove delivered its first prototype along with a virtual reality (VR) use case with Volkswagen (About Us | Meet the Team, n.d.). Over the years, the company has developed two different models of haptic feedback gloves, the DK1 and the Nova. Both of these gloves enable users to feel virtual objects in a simulated environment. This chapter provides a summary of SenseGlove's product history, current mission, and future ambitions. The chapter starts with a deeper dive into the basic principles of haptic technology. This context is needed to formulate an initial problem definition.

1.1 THE TEAM

Currently there are 25 employees at SenseGlove (SG). The company structure can be found underneath. The company is based in YESdelft which is an incubator and startup ecosystem located in Delft.

Company structure

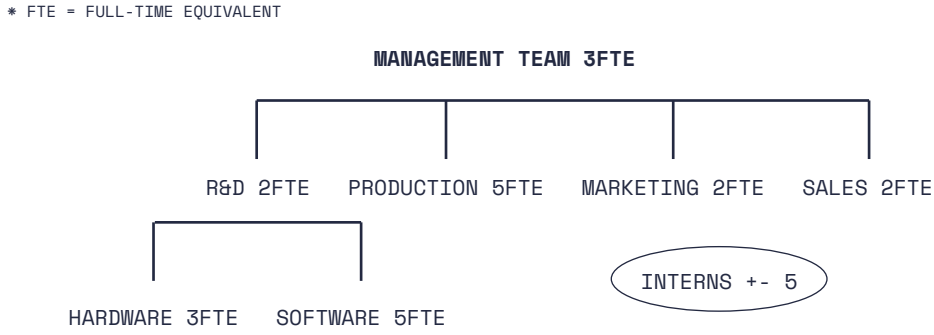


Fig. 1 The team

1.2 THE 4 DIFFERENT WAYS OF GIVING HAPTIC FEEDBACK

Haptic technology encompasses four main types of feedback: tactile, thermal, force, and vibrotactile. Tactile feedback involves perceiving patterns of pressure on the skin surface, enabling the perception of textures and shapes. Thermal feedback relates to temperature sensations and the flow of heat energy. Force feedback allows users to sense resistance, weight, and kinesthetic feedback. Vibrotactile feedback involves the perception of vibrations. These four types of haptic feedback contribute to the overall sense of touch experienced by users (Rubin, 2018). For a more elaborate explanation of this technology see appendix 8.

These four sensory channels combined is what we refer to as the human sense of touch. If all four were to be integrated in a haptic-glove and had the same accuracy as the human hand a human being would not be able to feel the difference between a real and a digital object. Of course this is not technically achievable now and will probably never be achievable.

Besides these four haptic technologies there are two other ways of giving haptic feedback, electro-haptic stimulation and ultrasound tactile feedback. Electro-haptic stimulation uses electric stimulation to stimulate the nerve endings to trick the user's brain into feeling contact. Ultrasonic haptic feedback uses ultrasound to create a disturbance in the air that the user can feel when they pass their skin across it. In this case the user does not need to wear any haptic device. These two forms of haptic feedback are not relevant for the rest of my thesis because both technologies are in a very early stage and not applicable to wearable haptic devices.

Finally there is hand and finger tracking. This is not a form of giving haptic feedback but it allows to determine where a user's hand and fingers are in space. This information is crucial to activate the different haptic senses in a haptic device at the right moment. Getting the tracking right is a must to create an immersive* experience and thus very relevant in relation to SenseGlove's products. Of course these terms specifically are only relevant for haptic gloves. In theory a haptic shoe would need feet and toe tracking.

** In virtual reality, immersion refers to the feeling of being fully present in a digital environment.*

1.3 FROM A RESEARCH EXOSKELETON TO A TRAINING GLOVE

The DK1

In 2017 SG introduced the DK 1, a haptic glove designed in an exoskeleton form factor (see figure 1.3.1). A total of 133 sets were sold. However, users encountered usability issues with the DK 1. It was challenging to put on due to the individual finger attachment requirement, and its bulky design was intimidating for those unfamiliar with advanced technology.

SG discovered that the DK 1 glove was primarily used for training, telerobotics, and research. Although the glove design worked well for telerobotics, there were significant opportunities for improvement in VR training. With the market for telerobotics being relatively small and the depletion of injection molds for the DK1, SG made the decision to develop a new glove specifically tailored for the VR training market.

Fig 1.3.1 SenseGlove DK1

The Nova

In 2021 SG released the Nova (see figure 1.3.2). This model, their current product, is designed to be worn like a regular glove. Usability was one of the most important design requirements for this new model making the Nova much easier to wear compared to the DK 1. Just like the DK 1 the Nova also has force-feedback, vibrotactile-feedback, and finger tracking which allow the glove to accurately determine the position of the user's hands in space, as well as the relative position of their fingers to their hand. It also enables the restriction of finger movement upon touching a virtual object. The addition of vibrations on the hand and fingertips further enhances the user's ability to interact with objects in a virtual environment.

An important note is that inside the Nova there is very limited space for components (Appendix 6). This means that for SenseGlove it is very difficult to either add functions to the glove without increasing the overall size or to make the glove more compact without having to eliminate features.

Currently, SG has sold approximately 250 to 300 sets of the Nova. While sales and production of the existing Nova system continue, SG is concurrently working on the development of the Nova 2 Since this development began towards the end of this thesis, it will not be further discussed in this report.

	DK1	Nova
Gloves sold	133	316
#Clients	97	223

Fig. 1.3.2 the Nova


SENSEGLOVE

1.4 SENSEGLOVE'S MISSION - MOUSE AND KEYBOARD OF THE FUTURE

SenseGlove's aim is to revolutionize the way people interact with computers by creating the future's equivalent of the mouse and keyboard. They do not intend to replace the current mouse and keyboard, but rather to become an equally vital part of the future of computing. The company envisions that in the era of the metaverse*, digital interactions will be as natural as real-life ones, and users will be able to touch, grab, hold, and feel virtual objects as if they are real in 3D environments. While these capabilities are currently available for professionals using the SenseGlove Nova, the company expects that in the future, they will become the norm for everyone, just like the mouse and keyboard are today. (SenseGlove, n.d.)

** The metaverse is a virtual universe or digital realm where individuals can interact with each other and digital entities, combining elements of virtual reality, augmented reality, and the internet to create immersive and interconnected experiences across various industries and activities. (Tucci, 2023)*

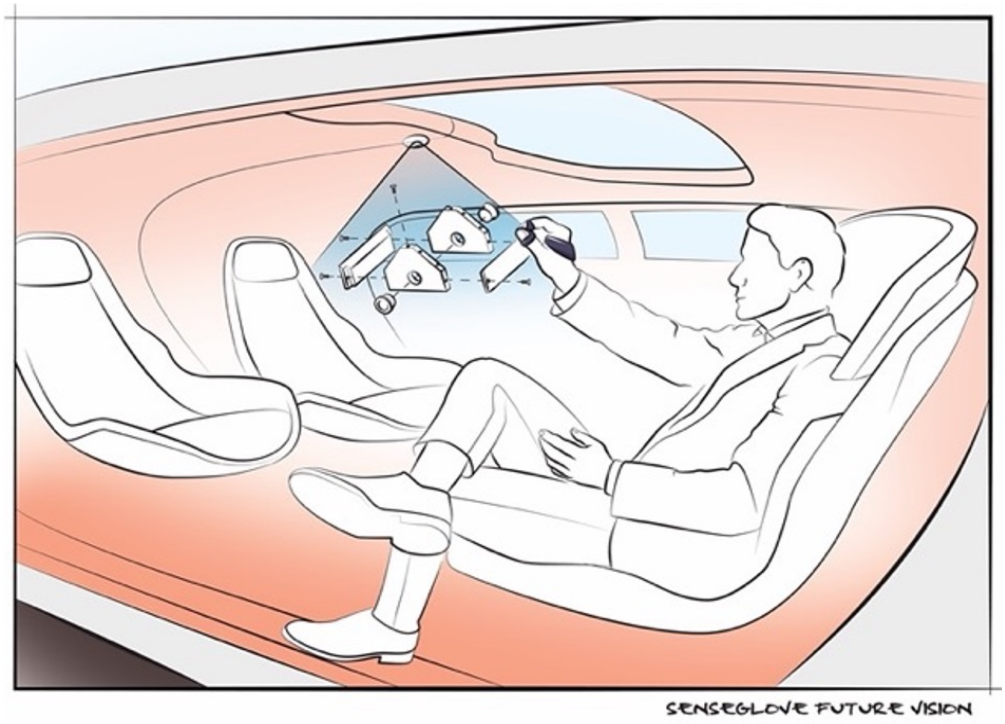


Fig 1.4.1 Mouse and the keyboard of the future (by Bryan Zaaijer)

This future vision is based on SenseGlove's expectations for the development of haptics and extended reality (XR) technologies. Based on the knowledge and experience of one of the founders Gijs, the company expects the XR hardware market to expand rapidly, with new devices becoming available that will enable more natural and immersive experiences (Fig 1.4.2). According to SenseGlove, this will lead to an increase in demand for haptic feedback devices like the Nova, as users seek to enhance their virtual interactions. The company plans to play a significant role in this market, providing innovative solutions that will transform the way people interact with technology. (SenseGlove, n.d.)

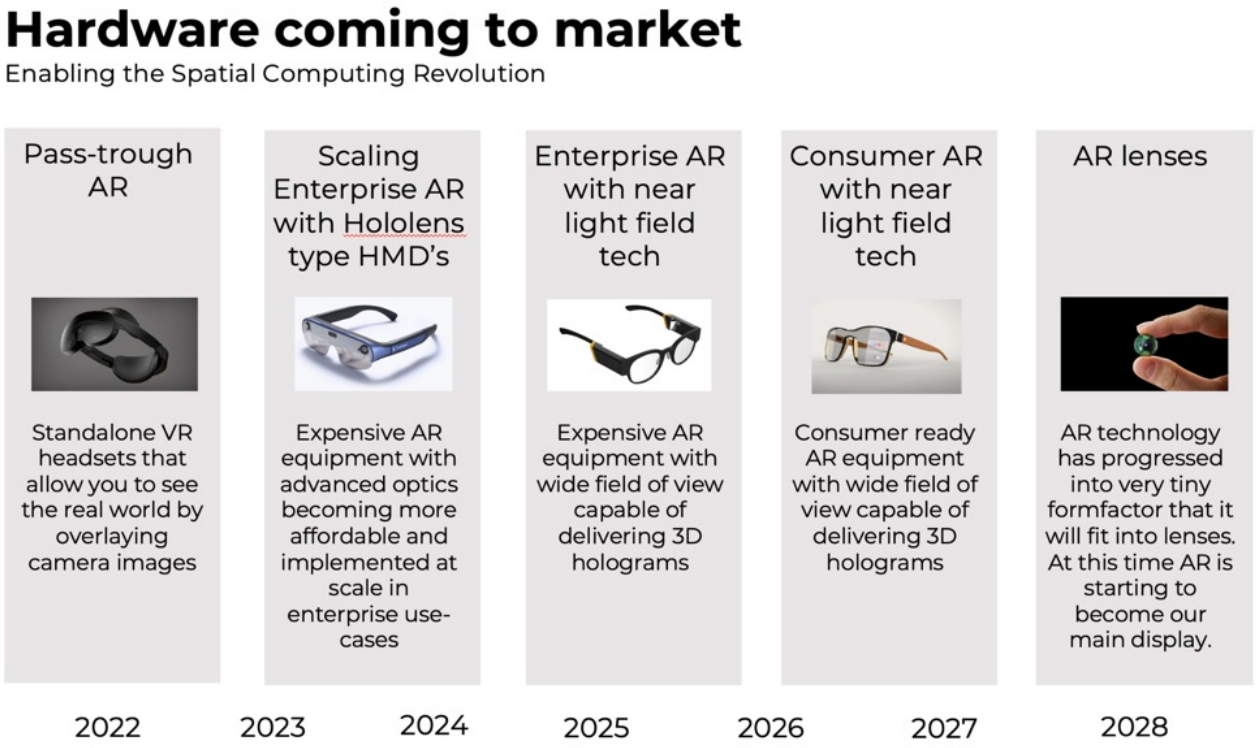


Fig 1.4.2 SG's prediction of the future development op haptics

1.5 SENSEGLOVE WANTS TO ENTER THE CONSUMER MARKET

According to SenseGlove's most recent roadmap (Fig 1.5), the company plans on entering the consumer market by around 2026, with the expectation that this will be achieved through the prosumer market. Prosumers are professionals who adopt products and technologies from their work and start using them at home. This has been a common trend with many tech products that have found their way into the consumer market. Examples are the smartphone, which had a breakthrough when bankers started using the Blackberry to send emails from their phones (Anderson, 2021), and 3D printers, that initially were being used in industry but are now commonly used at home as well (Thomas, z.d.).

Through these first glimpses of SenseGlove's ambitions it became apparent that SenseGlove aims to enter the consumer market through the development of a pro-sumer ready product. However, what this product would be and how it would help SenseGlove to achieve this aim remained unclear to me. This seemed to be a suitable challenge for me to tackle within my graduation research, so I formulated the following research question:

How can SenseGlove enter the consumer market through a prosumer product?

In attempt to provide an answer to this question, I set out to answer the following sub questions first:

(1) What consumer market should SenseGlove's prosumer product address?
(2) To what extent is SenseGlove's ambition to enter the consumer market realistic?

> *a. Is the price of the product in line with the customers willingness to pay?*
> *b. How is the AR/VR market developing?*
> *c. To what extend does SG's product add value to the potential market.*

To answer RQ1 a list of potential markets will be formulated by discussing the topic with the people working at SG. The theoretical framework of blue oceans will be used to assess this list and select the final market to further research (Blue Ocean Strategy, 2023).

RQ 2 will be answered by:

a. Assessing the customers' willingness to pay by analyzing surveys that users of the Nova filled out at different international technology fairs.

b. Analyzing the AR/VR market by reviewing literature on this topic.

c. Executing an observational research to determine the added value of a haptic device for the potential market.

As will be further explained in section 3.6, the outcome of this initial research led me back to the drawing board of my graduation research.

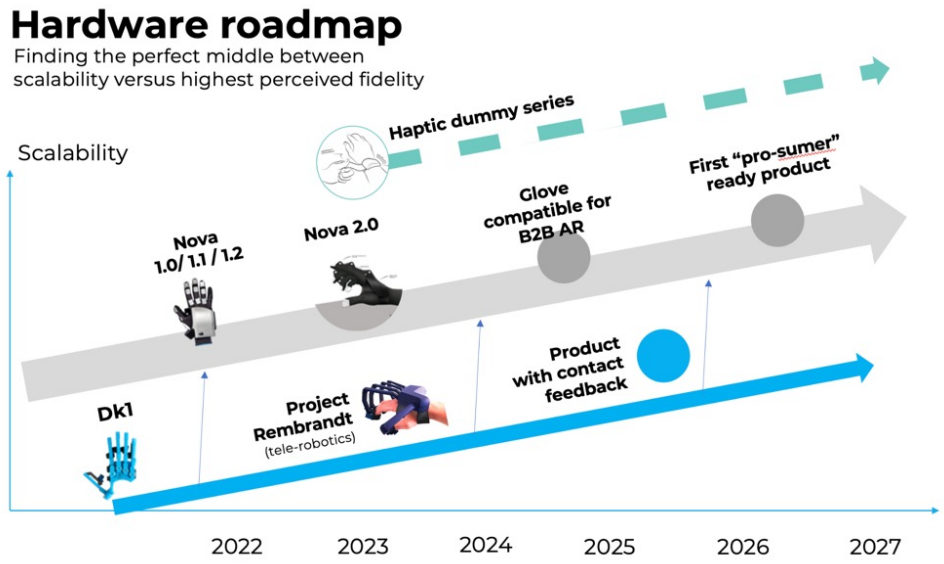


Fig 1.5 SG internal hardware roadmap

02

HAPTIC TECHNOLOGIES & CONSUMER MARKET.

Chapter 2 provides an introduction to the potential markets for SenseGlove's prosumer product, utilizing the Blue Ocean Strategy as a framework to assess their viability. Among these potential markets, the online meetings market stands out as particularly promising. Additionally, this chapter conducts a comprehensive analysis of the augmented reality/virtual reality (AR/VR) market and considers pricing factors. Furthermore, the chapter delves into observational research that explores the significance of haptic technology in enhancing the value of online meetings.

2.1 POTENTIAL MARKETS

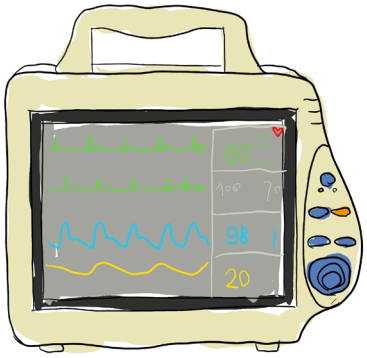
In order to introduce a prosumer product into the consumer market, it is crucial to identify a market segment that encompasses the active participation of both consumers and professionals. Furthermore, the chosen market should possess the potential to leverage haptic technology for its benefits.

After engaging in multiple discussions with individuals within SG, several market options emerged that captured my interest. However, only markets that encompassed both professional and consumer domains were deemed suitable for selection. An example of a market that was therefore excluded, was that of VR/AR virtual prototyping. While this market did show promise, it focuses exclusively on professionals and not on consumers.

Taking all into consideration, the following four markets emerged as viable options;

Gaming/esports industry

SenseGlove's technology could be a valuable addition to the gaming industry, as it has the ability to open up a realm of immersive experiences and heightened player engagement. By integrating haptic feedback into gaming peripherals, SenseGlove can provide gamers with a new level of sensory immersion, allowing them to experience the virtual world in a tangible way. Furthermore, haptic gloves can offer a competitive advantage in the e-sports industry, providing players with precise and responsive feedback, enhancing their performance, and enabling them to better connect with the game. When looking at the gaming industry of the four selected industries this is the one least suitable for a prosumer product because there is not much of a professional gaming industry.

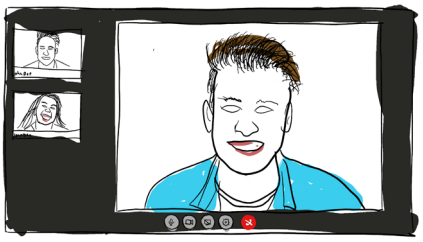


Health care industry (rehabilitation)

Another industry worth consideration is the health care and rehabilitation industry. The introduction of the Nova could revolutionize patient care, physical therapy, and rehabilitation processes by simulating and recreating real-life sensations. As such, healthcare professionals would be able to enhance diagnostic procedures, train medical practitioners, and offer personalized and interactive rehabilitation programs. Additionally, haptic gloves can facilitate remote patient monitoring and telemedicine, bridging the gap between healthcare providers and individuals in need of ongoing care. Finally, this market would be very suitable to start out with a product for professional therapists and then evolve to a product that consumers start using at home. SenseGlove currently has one client that uses the glove for this purpose already.

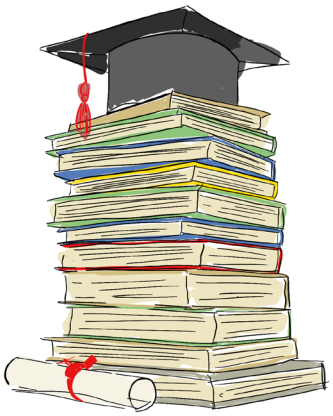
Online meetings

The online meetings might also hold potential for SenseGlove, introducing a new dimension of engagement and immersion to virtual interactions. With the increasing reliance on remote work and digital collaboration, haptic gloves offer a unique opportunity to bridge the physical gap between participants. By providing haptic feedback, these gloves can enable users to feel a sense of presence and connection during virtual meetings, enhancing communication and fostering a more immersive experience. By capitalizing on the growing demand for more interactive and engaging virtual meetings, SenseGlove could position itself as a key player in the online meetings market, redefining the way people connect, collaborate, and communicate remotely. Online meetings are also a perfect market for a prosumer product since meetings take place in both the professional and the personal sphere.



Education

Lastly, the education market could present a wealth of untapped opportunities. As educational institutions increasingly embrace technology-driven learning, haptic gloves offer a unique value proposition that can enhance traditional teaching methods. With the potential to revolutionize the way students engage with digital content, these gloves provide an immersive and tactile experience, enabling learners to physically interact with virtual objects and environments. Also education is a market for both professionals and consumers.



2.2 LOOKING FOR A BLUE OCEAN

Blue ocean theory

To evaluate these potential markets , the Blue Ocean Strategy has been used (Blue Ocean Strategy, 2023). This strategy, developed by W. Chan Kim and Renée Mauborgne, suggests that businesses can find success by creating uncontested market spaces, or "blue oceans," rather than competing in existing markets, or "red oceans." The framework provides a systematic approach to identifying and capturing new market opportunities.

A blue ocean strategy example is when Nintendo faced competition from industry giants Sony and Microsoft in the early 2000s. In response, they adopted a blue ocean strategy by targeting non-gamers and developing the Wii console, offering simplicity and interactivity. The Wii outsold competitors and attracted new customers (Team, 2022)

According to this theory, a 'blue ocean' market possesses the following characteristics:

1. **Uncontested market space:** A blue ocean represents a market space that is currently unexplored or underserved. There are no direct competitors or the existing competition is limited and ineffective. This allows companies to create and capture new demand without engaging in intense rivalry.
2. **Value innovation:** Blue oceans are created through value innovation, which means offering a unique value proposition that combines differentiation and low cost. Instead of simply improving existing products or competing on existing features, companies in a blue ocean pursue a different strategic path by delivering superior value to customers at a lower cost or with unique benefits.
3. **Expanded market boundaries:** Blue oceans typically extend beyond the existing market boundaries. They often attract non-customers or customers from alternative industries or substitute products. By targeting new customer segments or discovering latent demand, companies can tap into additional market potential and drive significant growth.
4. **Demand creation:** Blue oceans are characterized by the creation of new demand. Instead of competing for existing market share, companies in a blue ocean seek to make the competition irrelevant by offering innovative products or services that create entirely new market demand. This often involves redefining industry boundaries and challenging traditional assumptions.
5. **High growth potential:** Blue oceans typically offer high growth potential as they represent untapped or underdeveloped markets. By creating a new market space and capturing demand, companies have the opportunity for rapid and substantial growth compared to competing in existing, crowded markets.

Comparing the 4 markets

The table below compares the four selected industries with the five characteristics of a blue ocean.

	Gaming industry	Healthcare (revalidation)	Online meetings	Education
Uncontested market space				
Value innovation				
Expanded market boundaries				
Demand creation				
High growth potential				

When examining the criterion of "uncontested market space," it is evident that haptics is currently only extensively utilized in the gaming industry (Warren, 2020). This implies that introducing haptics within this market does not represent unexplored territory, where in the other three markets this would be the case. The same argument applies to the criterion of demand creation, because if haptics would be introduced in a new market this would redefine the boundaries of that industry which automatically leads to new demand.

Regarding value innovation, the conclusion is that none of these markets can be considered a complete blue ocean. Although haptics will likely offer a unique advantage in all these markets, it will always be an additional feature to an existing product or service.

With regard to expanded market boundaries, the gaming industry will not attract new customers to the market since haptics is already being applied within this industry.
Concerning healthcare, specifically rehabilitation, the introduction of this new technology will not lead to an increase in the number of patients requiring rehabilitation assistance.

However, in the context of online meetings and education, it is conceivable that haptics could attract non-users to the market.

Finally, it can be stated that all markets exhibit high growth potential since haptics has yet to become mainstream in any of the industries. However, looking at the education industry it is probably more difficult to realize this growth since budgets are often a limiting factor within this industry. The fact that budgets are limited in education was later confirmed when doing interviews with SG's clients who are in this industry (chapter 5).

Conclusion

Based on this analysis, both the market for online meetings and education appears to be closer to a blue ocean compared to gaming and rehabilitation. When choosing between online meetings and education three key arguments support the decision to further pursue online meetings.

Firstly, the market for online meetings experienced rapid growth during the pandemic and continues to expand presently (Tudor, 2022). This indicates a sustained and increasing demand for online meeting solutions.

Secondly, online meetings are utilized in both professional and private contexts. In contrast, the education sector exhibits a more ambiguous distinction between professionals and consumers, making it less conducive to introducing a prosumer product.

Lastly, the education market is more constrained by budgetary considerations compared to the online meeting market, thereby reducing its commercial appeal. The online meeting market, on the other hand, offers greater potential for generating revenue.

In summary, the analysis suggests that the online meeting market presents a more promising opportunity due to its significant growth, broader customer base, and higher commercial viability when compared to the education market.

2.3 PRICING OF THE CURRENT PRODUCT

When pursuing in the direction of online meetings it is important to assess the feasibility of a successful market entry. One of the most important indicators that a product is ready for the market is that the pricing is in line with what customers are willing to pay (Viswanathan, M. & Ahluwalia, R. 2012). Currently the Nova is priced at €5,000, based on the cost of production. From questionnaires taken by SenseGlove's staff at several tech fairs it can be concluded that the consumer is willing to pay between €150 and €500 for the current product (Appendix 3). An important reason for this is that users see the product as an add-on to their VR/AR headset. The current price of VR headsets on the consumer market is around $450 (Statista, 2022), and as long as SenseGlove's product is seen as an add-on product, it is difficult to sell the product at a much higher price rate. As Thomas T. Nagle writes in his book 'The Strategy and Tactics of Pricing', "pricing should be based on the value delivered to the customer, and that the price of an add-on product should generally be less than the price of the core product".

2.4 VR/AR MARKET ANALYSIS

An even more critical argument for the uncertainty of a successful market entry is that SenseGlove's product only goes along with a VR/AR headset. Therefore SenseGlove currently depends heavily on the development of this market. According to Gartner, a leading research and advisory company, the sales of AR/VR headsets were on pace to reach only 1.1 million units in 2019, which is significantly lower than previous projections. The report notes that while there has been a growing interest in AR/VR technology, the market has not developed as rapidly as expected due to a number of factors, including high costs, limited content offerings, and consumer hesitancy to adopt new technology. (Gartner, 2019).

However, it is important to consider not only the financial growth of the market but also the technological advancements. While SG has presented its predictions for the market development in Chapter 2, the actual direction of the market's growth remains uncertain. Many technology trend analysts forecast a shift from the current VR headsets to a more discreet design resembling regular glasses, offering a blend of real and virtual elements (Jabil, n.d.). However, there is also a significant number of skeptics who believe that VR/AR technology will never reach the mainstream, often citing the unsuccessful example of Google Glass (Weidner, 2023).

In conclusion, the future trajectory of the AR/VR market is uncertain. What remains certain is that SG's success, particularly in the consumer market, is heavily reliant on the direction and progress of this market's development.

2.5 UNCOVERING THE FEASIBILITY OF INCORPORATING HAPTIC GLOVES IN ONLINE MEETINGS

Interview

In section 3.2 the market for online meetings had been identified as a potential entrypoint for SenseGlove. Thus, the question arises what value a haptic glove can add to the context of online meetings.

In order to gain a better understanding of the needs associated with conducting online meetings and the potential benefits of haptics for professionals in these meetings, an interview was conducted with a professional, working in a field where online meetings are part of the daily routine (see Appendix 5). The following insights emerged from this interview:

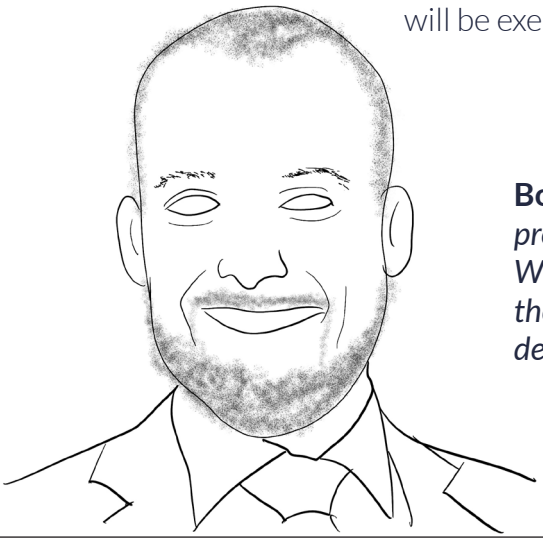
1. Within the corporate world, there is a strong incentive to reduce air travel by moving interactions to the digital sphere, as scrutiny of the environmental impact of air travel keeps growing.

2. Offline meetings provide more opportunities for personal interaction, which fosters stronger connections between parties. This is a reason why regardless of said scrutiny, corporates continue to opt for traveling by plane and meeting physically.

3. When online meetings are held in larger groups, non-verbal communication is often missed.

4. Online meetings also have their advantages, such as the ability to easily take notes, look up information during a conversation, or make amends to a slides that are about to be presented based on the direction a meeting is taking.

Based on this interview, the four promising points above were identified, prompting further investigation into the potential added value of haptics in online meetings. To better define this 'value' an observational research will be executed. The next paragraph elaborates on this research.



Bob Metz: *'a change has taken place. We will also sell proposals and do pitches online after the pandemic. When it comes to delivering bad news, it is nice to be there physically to also have some bonding before delivering the news'*

Observational research

In order to investigate the potential value of haptics in online meetings, an observational research study was conducted to explore the interactions that take place in different types of meetings, both online and offline (7 types of meetings (and how to get them right), n.d.). Seven distinct types of meetings were attended and studied, including decision-making, problem-solving, team-building, brainstorming, one-on-one, quarterly planning, and check-in meetings. Examples of the meetings attended include a brainstorming session at SG (see Fig. 2.5) and coach meetings at the faculty of Industrial Design Engineering.

The objective of the study was to identify interactions that could potentially be replicated in online meetings through the utilization of haptic technology. The research followed a naturalistic observation approach, which involved observing and documenting behaviors in their authentic setting without any interference or manipulation by the researcher (Neuman, 2000).

Fig. 2.5 brainstorm session at SG

The observation protocol for the meetings was straightforward and uncomplicated. During the observation, detailed notes were taken on the interactions among participants that involved the use of hands.

Through the course of observing these meetings, it became apparent that hands were primarily employed as a means of conveying body language, which is a crucial aspect of communication. However, it was determined that haptic feedback is not necessary to accomplish this in an online meeting setting, as a camera alone suffices.

Upon examining interactions that do require haptic feedback in an online context, the research yielded only minimal examples, such as a simple handshake. Hands were also found to be utilized for drawing out ideas and placing post-it notes in creative meetings. Presently, these actions are replicated in online settings already through the use of programs like Miro. Incorporating haptic gloves to perform such actions in online meetings would necessitate an entirely new approach.

In conclusion, the study found that the additional benefit of introducing haptic feedback solely for an "online handshake" is deemed insufficient to justify the investment required to implement such feedback. Furthermore, the initial observational research did not uncover other viable options within the current market of online meetings that warrant further investigation. To create more possible applications for haptics online meetings would have to take place in an AR/VR environment.

Consequently, it appears that the introduction of haptic gloves would not provide substantial added value in the existing market of online meetings. However, a future with a different way of performing online might create a demand for haptics.

2.6 CONCLUSION: CONSUMER MARKET NOT INTERESTING IN 2023-2026

To begin with, we can conclude that the market for online meetings initially appears attractive. It closely aligns with the concept of a blue ocean strategy and fits well within the prosumer strategy. Furthermore, interviews have revealed a corporate demand for conducting more meetings online to reduce travel.

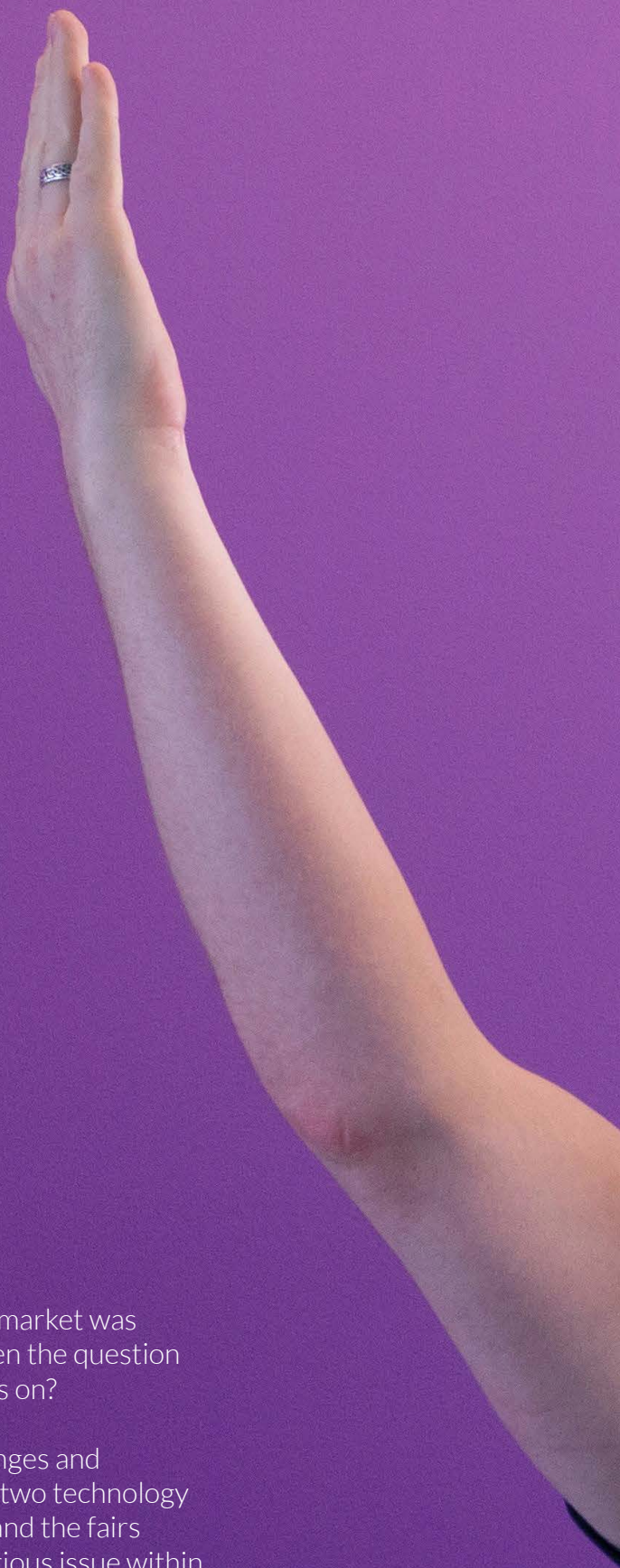
However, when considering the feasibility of SenseGlove entering the consumer market in the short term, we must acknowledge that this may not be the case. Not only is the AR/VR market developing at a slower pace than anticipated, but the production cost of their product is also not aligned with current consumer willingness to pay.

As history has often shown, both the demand for tech products and their production costs can change rapidly. But even if SenseGlove would be able to introduce a product that aligns with consumer budgets, the application remains questionable. The observational research has demonstrated that utilizing haptics in online meetings requires a completely new approach to conducting these meetings.

From a strategic product design perspective, it can be concluded that haptics in online meetings could hold great promise, but the technology currently surpasses the market. This forms a good example of the MAYA principle (Loewy, 1950). The MAYA principle suggests that when designing new products or technologies, they should be advanced enough to be attractive and innovative, but not so advanced that they become too unfamiliar or difficult for people to accept or adopt. In other words, finding the right balance between pushing technological boundaries and meeting user expectations and comfort levels is crucial. Examples of products that failed to adhere to this principle, such as Google Glass and Segway, illustrate the importance of this balance (Hartung, 2015).

Considering that haptics in online meetings are currently too advanced to be widely accepted by the consumer market, it would be wise for SenseGlove to refrain from pursuing this direction in the coming years. For now, it appears important to explore different areas where my expertise as a strategic product designer could be valuable to SenseGlove.

03
REFRAME.



BACK TO THE DRAWING BOARD

I was certain that pursuing the direction of the consumer market was not the right strategy for SenseGlove at this point. But then the question arose: How can I help SG to find the right strategy to focus on?

In order to gain a better understanding of both the challenges and strengths of SG I conducted a SWOT analysis, and visited two technology fairs where SenseGlove had a presence. Both the SWOT and the fairs provided valuable insights that ultimately uncovered a serious issue within SG, where a Strategic Product Designer has the potential to contribute to the solution. Chapter 3 delves into the SWOT analysis and the two technology fair visits.

At the end of the chapter, the new research question (RQ) that emerged from this reframing is presented.

3.1 SWOT

Intro - Method

In order to assess the challenges faced by SenseGlove and the company's ability to address them, a SWOT analysis was conducted. A SWOT analysis is a tool commonly utilized to identify the strengths, weaknesses, opportunities, and threats of a business or organization (Leigh, 2010).

The analysis involved interviewing eight individuals representing various departments within SenseGlove. Through these interviews, a comprehensive list of 75 strengths, weaknesses, opportunities, and threats was compiled (refer to Appendix 2). From this extensive list, the most significant arguments were clustered and summarized to create a concise SWOT overview which can be found on the next page.

Anne Hermans Productmanager
If VR does not become a big thing in the "at-home" market, SG will have little right to exist in the B2C market.

Bryan Zaaijer Creative Director
'The force feedback system currently used by SG is dependent on mechanical components, making it difficult to make the product smaller and lighter while still being affordable.'

Johannes Luijten CTO
'Currently, the force feedback system is only being used for hands, but applying it to other body parts is also possible. All of SG's tecnology is integrated into one product, but this could be multiple products in the future.'

Floris van Poele Production & QA lead
'The product is not mature enough at the moment to prevent errors in production. You really have to assemble it with feeling.'

The interviewees

Figure 3.1.1 depicts the individuals who participated in the SWOT analysis, along with a relevant quote extracted from their respective conversations. The selection of interviewees followed a purposive sampling technique (Gill, 2020), which involved a careful and deliberate selection process within SG to ensure a comprehensive representation. As part of this process, at least one individual from each department within SG was interviewed, aligning with the company's organizational structure (chapter 1).

Frank Goovaerts CEO
'Continuing the high growth of the company is becoming more challenging. To keep the same growth percentage we need our customers to innovate their processes and change how their staff do things. The Nova needs to move from the innovation department to the operational department, which requires a behavioral change within the companies of our clients.

Max Lammers Lead Developer
'The product has many software integrations, making it compatible with different software programs such as Unity, C++ API, and Unreal Engine.'

Nickolas van Acker Project Manager & Scrum Master
'SG uses a flexible working method, utilizing a twoweek scrum cycle that allows them to quickly test and integrate new features into their product and change their focus every two weeks.'

David Mullett Head of Business Development
'Clients compare the gloves with existing headsets that are far more developed, resulting in some disappoiment because of too high expectations. They purchase a more expensive "add on" that is of lower quality than the main product (the HMD).

Fig 3.1.1 SWOT interviewees with a quote.

STRENGHTS

- SG offers an **affordable** glove with force-feedback, vibrotactile feedback, and wireless connectivity.
- SG has the most **user-friendly** haptic glove on the market.
- SG utilizes a **flexible working method** with a two-week scrum cycle for quick testing and integration of new features.
- The team is diverse and highly skilled, enabling **in-house development** of the product from start to finish.
- SG has innovation power and can **quickly implement new ideas** with its efficient team.
- The product has software integrations with Unity, C++ API, and Unreal Engine.

OPPORTUNITIES

- The current market for virtual force feedback gloves is small and has **little competition**.
- Synergetic development with other companies interested in research by SG.
- The **XR (AR/VR) market is growing**, providing opportunities for SG's haptic gloves.
- Potential future B2C market for XR haptic devices.
- Haptic gloves can be a valuable addition to the gaming industry.
- Increasing adoption of remote telerobotic and at-home working environments.
- The **market for VR headsets is growing**, benefiting SG's growth.
- Potential for **SG to be acquired by a larger company**.
- Applying force feedback to other body parts and creating multiple products in the future.

WEAKNESESS

- SG is highly **dependent on a few individuals** within the development team.
- Assembling the product in-house can lead to **small mistakes and require after-sales support.**
- Some workers in the assembly department are not focused on quality, leading to occasional errors.
- The product undergoes numerous iterations, resulting in **production mistakes** and retaining prototype elements.
- **Client expectations may be too high**, leading to disappointment in comparison to more developed headsets.
- After-sales services account for a significant amount of time due to installation and software development queries.
- Using a pull strategy carries risks of meeting unexpected high demand and supply delays.
- **Lack of clear vision** and communication issues within the company.
- **Dependency on the XR-headset market**.
- The product still needs of **move from the innovation department to the operational department** of our clients

- Competition from big players like **Apple, Microsoft, and Meta entering the haptic wearables market.**
- SG's focus on hand-based haptics may limit opportunities in sectors with no demand for hand-based haptics.
- Shortage of electronic parts and potential supply chain issues.
- **Uncertainty if VR does not become popular** in the at-home market.
- Stagnation in telerobotics development.
- Economic crises impacting SG's growth.
- **Lack of access to HMD data** and front-facing cameras. (access to this data is crucial to have the glove work with the HMD)

THREATS

Summary

SenseGlove stands out as a company offering a cost-effective glove that incorporates force-feedback, vibrotactile feedback, hand/finger tracking, and wireless connectivity. This set of features positions SenseGlove as the most user-friendly glove currently available in the market. An agile and flexible working approach is adopted by SG employees, enabling rapid testing and seamless integration of new features every two weeks

One of SG's notable strengths lies in their ability to handle the entire product development process in-house, from initial concept to the final product. This approach harnesses their innovative capabilities and leverages the efficiency of their compact yet highly effective team. Additionally, SG holds intellectual property rights for certain software and hardware components, further setting their product apart from competitors. The glove boasts seamless software integrations with popular programs such as Unity, C++ API, and Unreal Engine, facilitating broader compatibility and expanding its potential applications.

Adoption is a red flag

'Continuing the high growth of the company is becoming more challenging. To keep the same growth percentage we need our customers to innovate their processes and change how their staff do things. The Nova needs to move from the innovation department to the operational department, which requires a behavioral change within the companies of our clients- Frank Goovaers, CEO SenseGlove

This statement made by Frank, the CEO of SenseGlove, resonates with a sentiment that emerged consistently throughout all eight interviews. From these insightful conversations, it became evident that a key weakness of SenseGlove is that its product seems to get 'stuck' within their clients' innovation departments. To ensure widespread and regular usage of the product within the clients' companies, it becomes crucial for SenseGlove to transition into the operational department.

I found this particular problem very interesting to investigate further. Who are SenseGlove's customers, and what do they do with the glove? And how is it that the product is only used by innovation departments?

A first step towards answering these questions was made by accompanying SenseGlove to two technology fairs in Rotterdam and Barcelona. The next paragraph elaborates on these visits.

3.2 THE CUSTOMER EXPERIENCE OF SENSEGLOVE (VISITING FAIRS)

SenseGlove actively participates in approximately 10 international fairs annually as part of their strategy to attract new customers and enhance brand visibility within the XR industry. I had the privilege of joining Sophie and David from the marketing department during the Immersive Techweek in Rotterdam, where we spent three days engaging with attendees. Additionally, I accompanied SenseGlove's team to the Mobile World Convention in Barcelona, a week-long event featuring an expansive hall showcasing promising technology start-ups

These two fairs provided me with valuable opportunities to explore numerous cutting-edge technologies, enabling me to develop a more comprehensive understanding of the XR market. However, my primary responsibility was to offer product demonstrations of the Nova to attendees, allowing them to experience it firsthand. Here, we gathered feedback on their experiences by providing them with a survey to complete afterward (refer to Appendix 3 for details).
When doing these demos, I noticed how excited people and companies were about the product SG has developed. People were often amazed at what the technology is capable of, and right away started thinking about the future possibilities.

Giving demos also sparked many conversations with people about the Nova, in which I was asked many questions. Most questions were about the current applications of the product and where the product stands in its development. By answering these questions, which usually required me to run them by David and Sophie first, I learned a lot about the Nova.

The most important insight I gained is that 289 sets of the Nova had been sold to 207 different companies. This might suggest that there is already a significant implementation of the product. However I learned that none of these companies are actually applying the product in their business process now, and that there are still zero examples of companies that have placed a second order. This doesn't mean that SG's clients don't do anything with the product, but that after doing a test or a proof of concept the glove doesn't make it to the operational department.

To conclude, on the one hand organizations are super excited about what the Nova is capable of, but on the other hand we don't see any of them implementing the product in their processes. This discovery reaffirmed my decision to further explore this problem within the remainder of my graduation project.

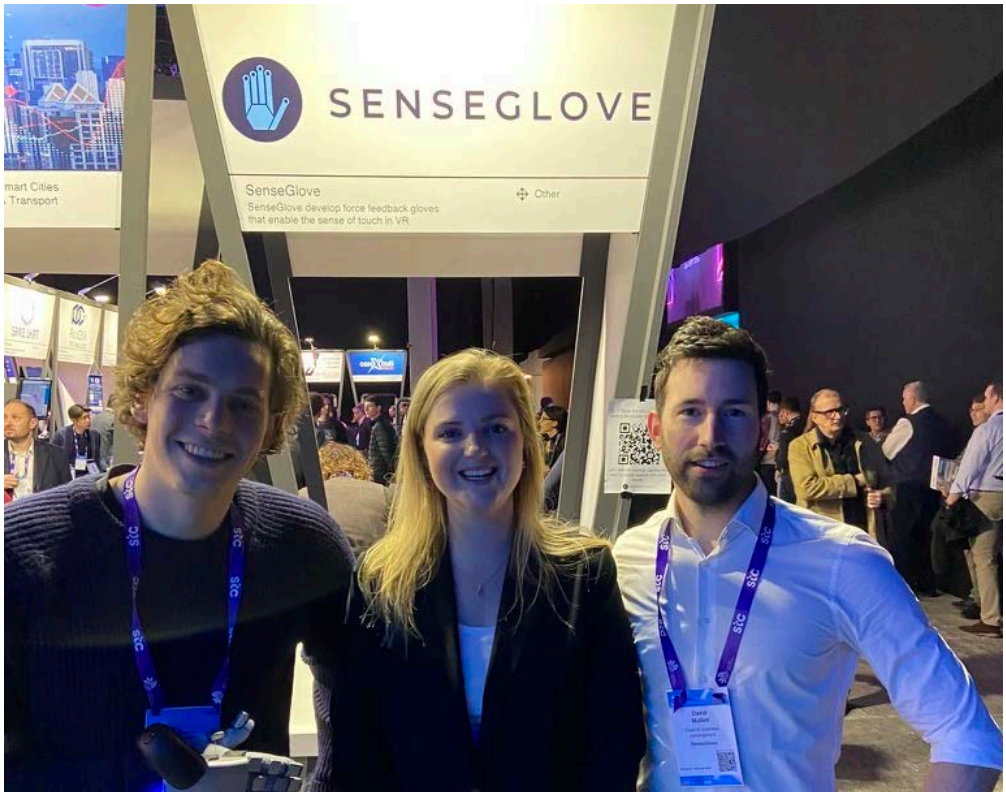


Fig 3.2 MWC Barcelona

3.3 FORMULATION OF A NEW RESEARCH QUESTION

Upon recognizing that the Nova device was not being integrated into clients' company operations, I initiated inquiries within the team at SenseGlove to determine the underlying cause. Despite receiving a range of plausible conjectures, no definitive answer could be ascertained. Notably, this lack of clarity can be attributed to the recent launch of the Nova in July 2021, as the SenseGlove team had not yet fully grasped the fact that their product had not gained traction among clients following the initial pilot projects. Consequently, this circumstance prompted the formulation of the subsequent research question:

RQ 2: What interventions can help SenseGlove to increase adoption in their customers' organizations?

To provide a structured approach to answering this question, the following sub questions have been identified;

(1) Who are SenseGlove's clients and what is their use of SenseGlove's products?

(2)Why are clients not integrating SenseGlove's products at this moment?

(3)What needs to happen for enterprise clients to start integrating haptics in their company processes?

04
ADOPTION RESEARCH.

Within this chapter the first two sub questions will be addressed;

SRQ 1: Who are SenseGlove's clients and what is their use of SenseGlove's products?

To answer this question, there has been a collaboration with SG'S Sales department. Using data extracted from Monday.com, an online project management and collaboration platform used internally at SenseGlove, a coherent overview of SG's client base has been created (see fig. 5.2.1). This overview gives insight in which companies are SG's clients and what sector they are in. However, the exact application the company has for the Nova is not mentioned. This is one of the questions that will be asked during the interviews (see appendix 1).

SRQ 2: Why are clients not integrating SenseGlove's products at this moment?

SRQ2 will be answered using the grounded theory method (Glaser & Strauss, 2017), which will be further explained in paragraph 5.1. The data for this method was collected through qualitative research into SG's clients. By analyzing this data, insights were gathered that were used to answer SRQ2.

In the next paragraph (4.1) the steps taken to analyze SG's client base and select interview candidates are described. In addition it reports on the chosen methodology for analyzing the gathered data.

4.1 METHOD

Grounded theory

This study uses grounded theory. Grounded theory is a way to generate theories "grounded" in the data itself rather than relying on preconceived notions or existing theoretical frameworks. As such, the outcome ought to be closely connected to the experiences and perspectives of the participants being studied.(Glaser & Strauss, 2017). The reason for using this method is because SRQ 2 is about understanding the clients perspective and therefore building a theory from their experiences. This should give us insight into RQ2

Grounded theory involves systematically analyzing and coding the data to identify patterns, concepts, and relationships, which are then organized into a theorectical framework. This process typically unfolds through the following iterative steps (Creswell et al., 2007):

1. Data collection: For this study 30 minute interviews were conducted to gather data. The interviews were recorded and later transcribed.

2. Initial coding: This first round of coding was done with the data from the first 8 interviews. It involved systematically examining the data line-by-line and assigning descriptive labels or codes to capture the main concepts or ideas. This process allows for the identification of patterns and relationships within the data.

3. Axial coding: In this step, the first findings were categorized and connected. The relationships between different codes were identified and categories and subcategories were developed by grouping similar concepts together.

4. Theoretical sampling: In this phase more interviews were conducted to further explore and refine the insights that were found. This helps in validating and expanding these insights.

5. Theoretical saturation: As more data was collected and analyzed, the concepts and categories became more refined and the insights started to reach a saturation point where new data did not significantly alter the emerging list.

6. Constant comparison: Throughout the process, new data and emerging concepts were constantly compared with existing codes and categories. This iterative process helped in refining and developing a final list of insights.

7. **Theoretical memos:** During the process detailed notes called "theoretical memos" were maintained, documenting thoughts, ideas, and reflections on the emerging insights. These memos aid in the organization and development of the insights.

8. **Theory development:** During this study there was no new theory developed. The grounded theory method was used only to gather bottom up insights that will help answering the RQ.

The results of this graduation research, as documented in section 4.2, have been structured according to the above steps.

Sampling

The interviewees for the study were selected using a combination of Purposive-, Snowball- and Convenience sampling (Gill, 2020).

Purposive sampling	involves deliberately selecting participants who possess specific characteristics relevant to the research objectives, often used in qualitative research to gain in-depth understanding or explore specific phenomena.
Snowball sampling	is a technique where participants are initially recruited based on specific criteria and then asked to refer to other individuals who may also meet the criteria, creating a chain referral process useful for researching hidden populations or sensitive topics.
Convenience sampling	involves selecting participants based on their easy accessibility and availability to the researcher, often due to time, cost, or logistical constraints, but may introduce bias and limit generalizability to the wider population.

By combining these three methods, researchers can maximize the diversity and richness of participant perspectives, enhancing the overall depth and breadth of the study's findings.

In close collaboration with SenseGlove's sales department, a thorough review of the customer database for all Nova orders was conducted to identify 47 potential candidates for the interviews who could provide valuable feedback (purposive sampling). Customers who were still in the process of initiating a project or who had previously failed to respond to multiple emails were not considered (convenience sampling). After one reminder email and a follow-up phone call, a total of 13 customers consented to participate in an online interview. Furthermore, one customer provided written feedback on the Nova and one interviewee was recommended by another interviewee (snowball sampling).

Interview guide

An interview guide was put together to gather all relevant feedback on what barriers clients encountered in integrating SenseGlove's products into their company processes. The complete guide with the specific questions has been included in appendix 1. The interviews lasted about 30 minutes, and covered the following topics:

- Application of the Nova
- Feedback on customer service
- Feedback on software
- Feedback on hardware
- Integration of haptics into company processes

These topics were chosen as they encompass the key aspects of the product. However, the interview technique employed was semi-structured, allowing for flexibility to explore additional topics or delve deeper into interesting points raised by the interviewee. This approach was selected to facilitate the discovery of new insights from the clients perspective, as the research aims to gain fresh perspectives and uncover novel findings.

With the consent of the interviewees, the conversations were recorded and later transcribed. This data was then analyzed using ATLAS.ti (version 23.1.0), a computer software program developed for qualitative data analysis. This program facilitates the coding of text documents to identify patterns and derive insights. On the next page figure 4.1.2 shows an overview of how ATLAS.ti works.

Navigator

Search

Client interviews SG (3)

Documents (14)

1 1. 13
2 2. 25
3 3. 15
4 4. 15
5 5. 21
6 6. 13
7 7. 4
8 8. 17
9 Fe 4
11 9 14
12 1 13
13 1 7
14 1 6
15 1 9

Codes (3)

Arguments for not implementing 67

1. No company priority 4
2. A cultural change is needed 8
3. The costs of the glove are high 6
4. Glove is bulky 6
5. The glove is hard to put on/not easy to wear 7
6. Gloves are fragile (stuff breaks easily) 9
7. Gloves are difficult to clean 1
8. Gloves does not add enough immersiveness 1
9. Controllers are easier to use 5
10. Difficult to integrate movement on little objects (precision) 12
11. Difficult to move around in large virtual spaces 3
12. Sight is an essential element for haptics to work 4
13. handtracking is not good enough 1
14. Calibration is difficult 2
15. Users need assistance setting up the glove and headset 2

Client info 76

Coding round 1 88

Memos (2)

Networks (3)

Document Groups (0)

Code Groups (0)

54

Client interviews SG (3)

Speaker: 0

Alright, it's, it's recording now. So please d contact with David?

Speaker: 1

Yes. And about a year ago, I think I was ions in this direction in haptic feedback. all, I'm coming from rt, department of Si ment, field simulation D and my focus is ion of simulations using novel technolog R Technologies. And we have created ov rototypes and we want to increase the im we thought about the trying the evaluatev e market, how mature is this technology have several companies and we havedec e of them. So one of them was Sales Clu rnal evaluations and the other onealso so d so far I think we received them back in aken. The gloves, andunfortunately we h in summer, but then, cause there were so cts, we shifted backand we assumed that o continue. Now the evaluation of the Se

Speaker: 1

And so far we're satisfied. I mean it's a li ve, I mean very not so intuitive to wear, y, but that's also the feedback we getting ple. And what else? So software integrati s, I now we, and we expect to have a firs prototype demonstrator internally the ne e, we have two scope projects this year, . Sorry, I cannot reveal the, the use cases, ection of design and, and also, well how That's, I'm not revealing too much. Sowh ays important role? You? So you need, s

Speaker: 0

Can you repa repeat the, the last use case

Speaker: 1

So it's a use case where you have the feed so you can sense something on your hand

Speaker: 0

Okay. Cause about this, this use case, are s? I, I think there are use case in vr, not,

Speaker: 1

Yes, it's in VR.

Speaker: 0

Yes. And is it a, is it a use case you were controllers and you're now going to do u

Speaker: 1

Exactly.

Speaker: 0

Text Zoom: 125%

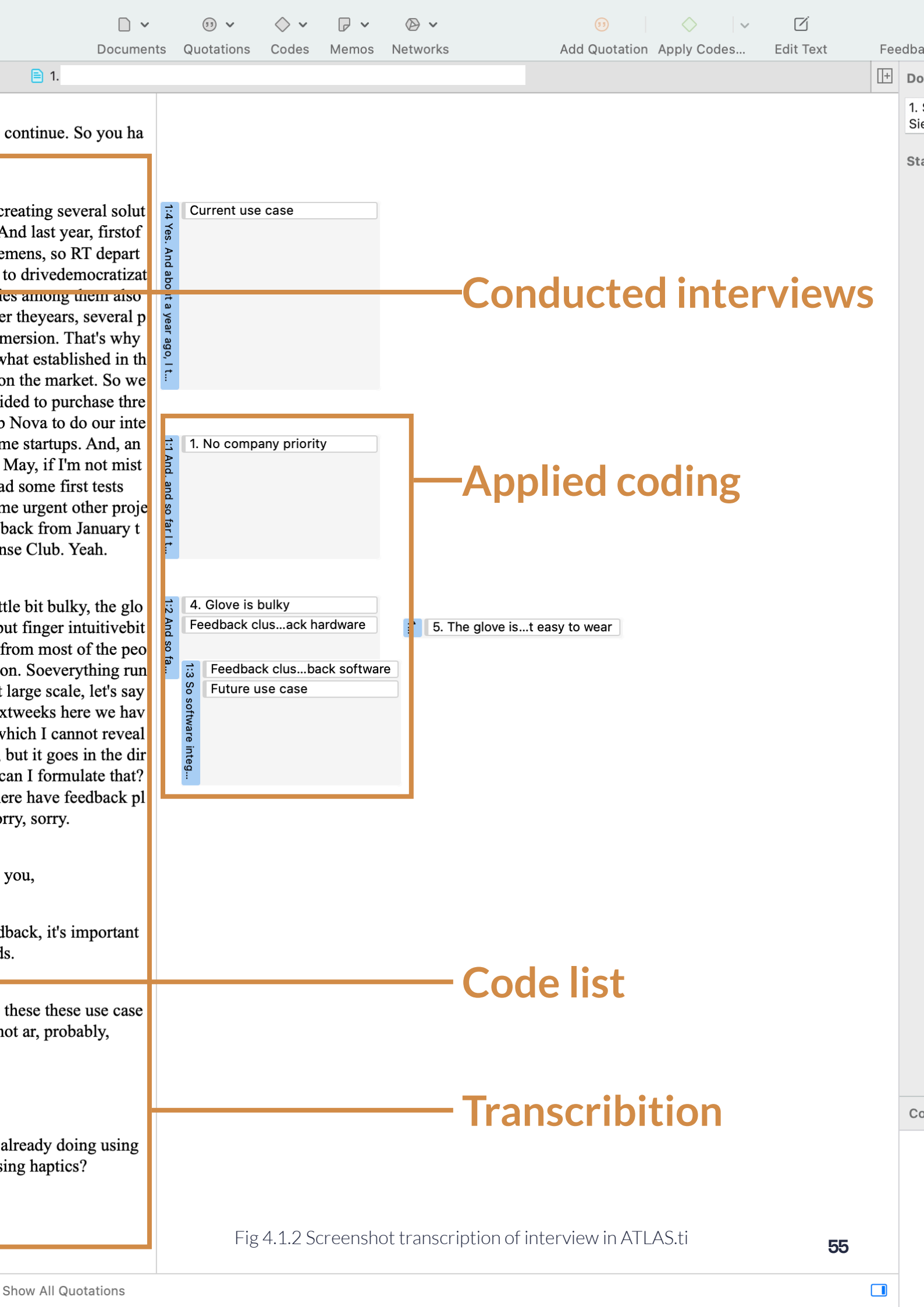


Fig 4.1.2 Screenshot transcription of interview in ATLAS.ti

Data collection

All interviews were done in English and online using Zoom. Zoom was also used to make a recording of the interviews. The transcription of the interviews was conducted using the software provided by Rev.com. This automated transcription tool boasts an accuracy rate of 95%, which proved sufficient for comprehending the text and extracting insights.

Initial coding

The data analysis process begins with open coding of the first few interviews. In this phase, coding was applied based on what initially appeared to be logical. Examples of these codes are presented in Fig 4.2.1 and 4.2.2. It is notable that both highly general codes, such as 'positive feedback,' 'reason for not implementing,' and 'interesting note,' as well as highly specific codes, such as 'only using thumb and index finger,' were utilized.

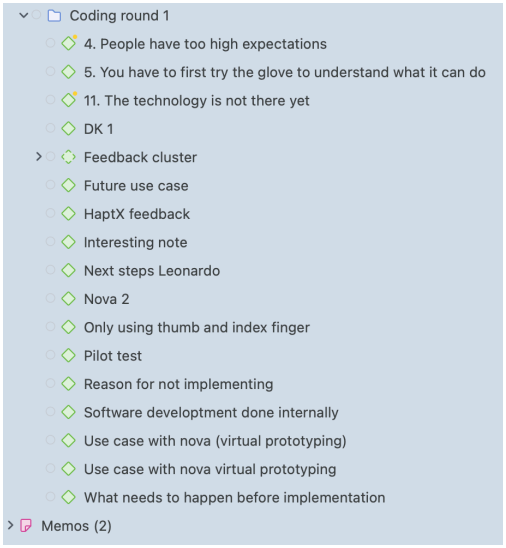


Fig 4.2.1 screenshot coding round 1

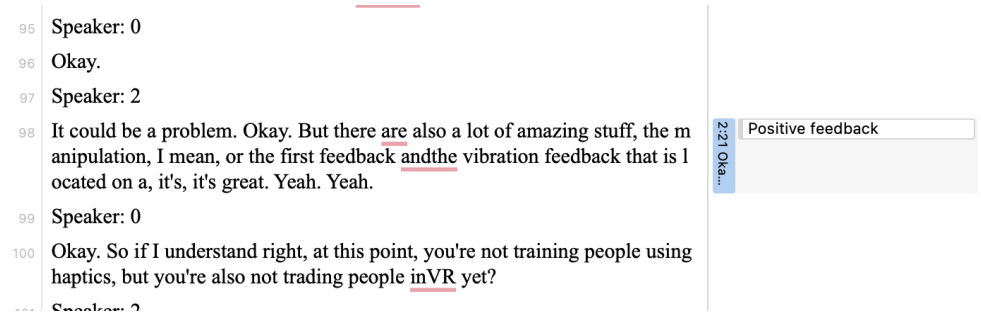


Fig 4.2.2 screenshot of coding example

During this first code round also more general information was coded like 'function of interviewee within the company' or whether the software programming was done internally or by an external party. The reason for also coding this kind of info was to gain a better understanding of the context. Later during the axial coding these codes were left out.

Axial coding

Following the completion of eight interviews, the data underwent a coding process to identify patterns and overlaps among the various codes. Some codes needed to be regrouped, while others required further subdivision to ensure specificity. The research objective was to address the question: "Why are clients not integrating SenseGlove's products at this moment?" Consequently, the axial coding process focused on identifying arguments that elucidate the reasons for the lack of product implementation. An illustrative example of this coding process is presented in Figure 4.3.3, where a segment initially coded as 'feedback' was later refined to 'costs are too high.'

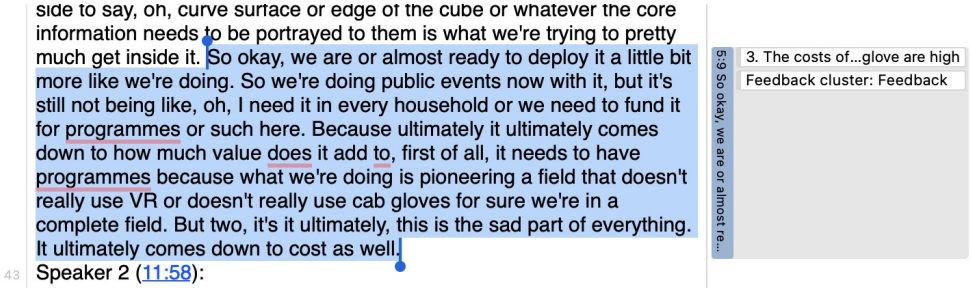


Fig 4.2.3 screenshot coding iteration example

Figure 4.2.4 provides an example of content that was identified as an argument against implementing the glove at this juncture. In this instance, the interviewee expressed concerns about the glove's weight, particularly when worn for extended periods. This feedback was coded as 'glove is bulky' to capture the essence of the interviewee's statement.

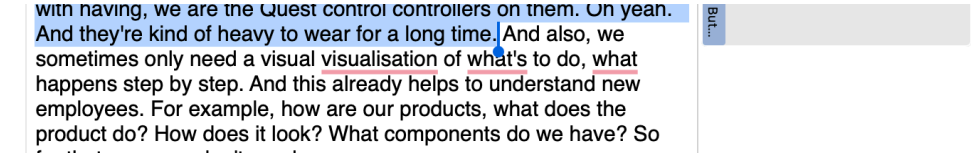


Fig 4.2.4 screenshot coding example 2

Furthermore, codes such as 'main business of the company' and 'Feedback on DK1' were eliminated during this second coding round, as they did not contribute to addressing the research question.

Following this iteration, a list of 18 arguments advocating for not implementing SG's product remained. Using these codes as a guide, additional interviews were conducted and further coding was performed.

Theoretical saturation

Upon conducting 12 interviews, it became evident that no new arguments emerged regarding the non-implementation of SenseGlove's product since there was no need for creating new codes. Subsequently, by consolidating several codes, a codebook was eventually developed, containing 15 arguments explaining why clients have not yet implemented the Nova (refer to Figure 4.2.4).

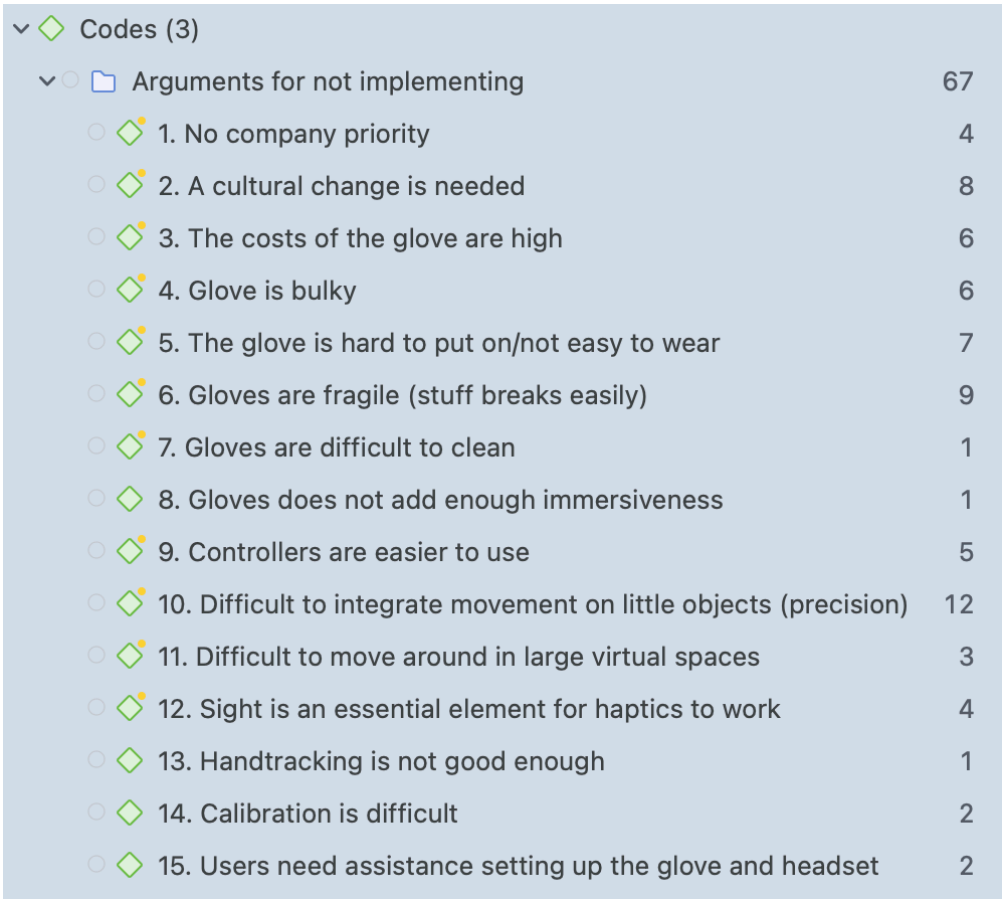


Fig 4.2.4 final code book

During the final phase of the analysis, the remaining three interviews were coded using the existing codebook. Importantly, no new codes were added to the book, indicating that the data collected and analyzed thus far has reached a point of saturation. Saturation refers to the point at which additional data collection is unlikely to provide new or different insights. This suggests that a comprehensive understanding of the research topic has been achieved through the existing dataset and analysis.

Final insights and discussion

The 15 codes in the codebook serve as the foundation for why clients are not yet implementing Nova. These codes provide a comprehensive understanding of the factors contributing to the non-implementation. Underneath all 15 arguments are explained, illustrated with a quote from one of the 15 interviews to provide a better understanding of their meaning. Finally, after each argument there is a short discussion. (#).

1. **No company priority**
   Several companies indicated that they are not currently focusing on the Nova because they have other priorities within the company.

   "I think it's a bit of everything, but mainly because of a missing capacity to develop that we have a student and he has a specific time to do this project and with more time it would be better."

   Sense Glove provides hardware that is not an industry standard. Especially organizations currently involved in VR-related activities and already equipped with digital environments should be able to seamlessly transition to the Nova. However, this transition is not currently straightforward. Additionally, clear and informative tutorials could help overcome this priority issue, but SenseGlove already does this. Another approach to address the issue of priority could involve creating better demos and sending them, along with a set of gloves and a headset, to companies.

2. **A cultural change is needed**

   Cultural change is an important and frequently heard argument for why it is difficult to implement haptics. This can refer to end-users who find it challenging to adopt this new technology, as is made clear b the following quote:

   "So I would say they are a little bit scared that it's too complicated and they cannot easily use it."

   But sometimes the problem is also internal, and certain departments need to be convinced to allocate a budget for integrating haptics into VR training.

   This problem is understandable, particularly at lower levels of a company. When for example initially working on a real plane, the training in VR may not be that appealing. However, training with haptic gloves does not necessarily replace real training. At higher levels of a company, such as the management team, a simple calculation showing a cost reduction could possibly bring about the necessary cultural change.

3. The costs of the glove are high

Another commonly heard argument is that the cost of the glove is high. Currently, a set of gloves costs €5000 and without sacrificing functionality, this price is not likely to decrease significantly.

This argument is particularly mentioned by non-commercial customers such as research institutions or healthcare companies because their budgets are often limited. However, there are also commercially very successful companies that sometimes struggle with the price. For example, a company that operates within the military sector aspires to use the Nova to remotely train customers to use certain equipment. This VR training should prevent their clients from damaging parts during physical training, which costs a lot of money. The company has calculated that they would need 50 sets of gloves to execute this plan. Where an investment of €5000 is not a problem for such companies, the total cost of €250,000 does raise the question whether the benefits outweigh the costs.

'But if we think of making a scalable product out of it for our use case, the training is supporting them. And if we have 50 trainees somewhere, we would have to buy 50 gloves. So then the training costs will increase. And our intention is actually to reduce the costs of traveling and trainers and all the surroundings of the training set up.'

SenseGlove may have the potential to address this issue, as the production costs are much lower than the selling price of €5000. Alternatively, exploring other product options could be a solution. The current product is complex and challenging to produce at the current volumes with a lower cost. One strategy could involve starting with a specific budget and then determining what type of haptic product can be developed within that budget. Consumers indicate that the price range could be between €150 and €500 (Appendix 3).

4. Glove is Bulky

The bulkiness of the gloves is a problem for many companies, especially when worn by a smaller person, as this affects the natural feel of interactions. An important factor in this is that the controllers of the VR headset still need to be attached to the glove at this moment, which adds significantly to the overall bulkiness

'And the fact that you have to mount the controller to the glove, that's something that takes a lot of space and feels clunky for the user. So that's the development we're waiting for.'

This issue is mainly due to the mounted controllers. SG is currently working on the "Folmertron," a camera that can be attached to the head-mounted display (HMD) and track the gloves without the need for controllers. However, this means having an add-on product in order to use an add-on product. Another option would be to integrate this camera into the glove itself, allowing it to determine the glove's location based on the surroundings. Nevertheless, it appears that neither of these two solutions will be viable in the near future. In theory, the gloves could be tracked using the cameras already integrated into the HMD, but SG does not have practical access to such cameras. This could be resolved by establishing a collaboration with a company like HTC, Meta, Picco, Quest, etc. However, whether these companies are open to collaboration is unknown, and such collaboration would also exclude a significant portion of the market.

5. The glove is hard to put on/not easy to wear

Many users also find it difficult to put on and take off the glove. Although the Nova has made a huge leap in this regard compared to the DK1, it is still often heard as a point of feedback.

'There are some limitations, but I think the bulkiness of the VR glove and its difficulty to wear are the two main factors.'

Although SG has devoted considerable attention to this issue, customers still mention it as a problem. This could be because the product is currently marketed as "a wearable device that is easy to use," which may create incorrect expectations. Alternatively, one could move away from a glove design and incorporate haptic capabilities into another product like controllers, which do not require wearing.

6. **Gloves are fragile (some parts break easily)**

   This problem occurs when working with inexperienced users who are not familiar with the technology. For example, if the glove is dropped, there is a considerable chance that something will break, causing it to become defective.

   'The fingers come off too. The little fingered loops. Those little things come off, I have to fix them every time I work with a client, at least one of them'

   Although clients mention fragility at SG, there are almost never products being returned due to breakage. While gloves used extensively may exhibit wear over time, actual breakages seem to be rare. Clients may perceive the gloves as fragile due to their current appearance, which seems somewhat prototypical. Only the tracking mounts occasionally break, but they can be easily reprinted and replaced.

7. **Gloves are difficult to clean**

   This argument was mentioned by one client. It's relevance may be questioned, as the gloves are always used in an inside environment where they cannot get very dirty. The inside glove can be removed and washed for hygienic purposes.

   But also the glove itself in order to clean it would be a problem.'

   The gloves are currently washable, but in practice, no clients nor SG ever does this. Besides, only one client mentioned the gloves being difficult to clean. Additionally, replacing the soft glove is also an option. This costs about €300 per set.

8. **Gloves do not add enough immersiveness**

   Depending on the client's use cases for the glove, the gloves sometimes fail to add sufficient immersion to the total experience. Only when the user is actually grabbing objects in the virtual environment to move them around immersiveness is increased by the haptic gloves.

   'It's in there and then it can be very useful if you give the character a push. For example, that you feel something like counter pressure. But that's not quite what the gloves work for.'

This point is challenging to pinpoint precisely as it likely involves a combination of hardware and software feedback and the overall user experience. Consequently, providing concrete solutions for this problem is difficult.

9. Controllers are easier to use

Two clients mentioned that they find working with controllers easier for now.

"Because we found them easier to use, and people who come and see what we do also find the controllers easier, that's basically the motivation."

Indeed, it is true that controllers are generally easier to use compared to gloves. However, gloves offer numerous other benefits over controllers, such as the ability to interact with and grab objects, providing a more immersive experience.

10. Difficult to integrate on little objects (precision)

This is an often heard argument. When interacting with smaller objects the integration of the glove just doesn't work so well. As a result many use cases with fine motor movements are being eliminated (see quote).

'Yeah, that's what we do in healthcare. Most of our psychomotor tasks involve fine motor movements, such as inserting a catheter, or performing procedures like nasogastric tube insertion. These tasks require a lot of tactile feedback, which the glove just doesn't provide yet.'

The challenges related to integrating gloves with small objects are highly technical. These issues closely relate to the current technique employed for force feedback, which utilizes a mechanical system with wires. The presence of only one passive force feedback actuator per finger restricts the ability to vary the application of feedback. Additionally, due to the limited range of motion inherent in finger-based systems, there is minimal margin for error.

11. Difficult to move around in large virtual spaces

Compared to controllers it can be a bit more complicated to move though larger virtual environments wear gloves. Where with a controller you can teleport to other spaces using a button, with gloves specific hand gestures are required.

'A problem is teleportation, I mean the people cannot teleport in an easy way.'

The problem of navigating large virtual spaces can be resolved by implementing hand gestures. SenseGlove has a solution for this issue and can provide it to clients, enabling smoother movement and interaction within expansive virtual environments.

12. Sight is an essential element for haptics to work

This argument came from a company that develops technology for blind people. They found that without sight the feedback of the gloves is much less realistic. Adding audio instead of sight however also had positive results.

'Without sight users never ever will get the true representation of that object.'

This problem is directly connected to the overall immersiveness of the experience and the effective integration of haptics with small objects. Visual cues play a crucial role in enhancing the effectiveness of haptic feedback, as they provide contextual information that complements the haptic sensations. However, this is what the gloves are designed for. The whole concept is to combine visual and audio cues together with haptic feedback to create the illusion of touch.

13. Hand Tracking is not good enough

Multiple clients gave feedback that the hand tracking is not working so well. This for example results in people pinching through an object which makes their experiences way less immersive.

'And the other one would be the hand tracking. That's not accurate enough'

The problem that occurs with hand tracking not working right often is the result of not properly calibrating the gloves.

14. Difficulty in calibration

Proper calibration of the gloves does not always work well, and as a result, finger tracking does not work correctly. Calibration can be especially challenging for people with limitations in their hands.

"So, the calibration of the gloves was performed. This is challenging for healthy individuals and even more difficult for individuals with impaired hands."

The calibration process itself is relatively straightforward. The user of the glove has to first make a fist with their thumb inside, followed by giving a thumbs up it calibrates the gloves. However, it is unclear why some clients still find it challenging, necessitating further research to understand their specific difficulties. It is possible that the technology is still novel to users, requiring repeated calibration to become more familiar with the process. Moreover, individuals with hand limitations may encounter additional challenges with calibration.

15. Users require assistance in setting up the glove and headset

A common problem is that users who have no experience with the glove or require VR assistance may need help when using the glove. The following quote provides insight into how this can result in therapists not using the glove:

'The difficulty is that these therapists still have little feel for it and therefore spend too much time setting it up and such things. They just need to practice with it, and then it will get better. But it takes time, and that's the struggle you have in a healthcare institution.'

A significant aspect of this problem stems from the fact that virtual reality (VR) technology is still unfamiliar to most people. Learning new interactions and configuring the glove and headset accordingly takes time and practice.

Final Clustering

In the final step of the analysis, the insights gained have been organized into three distinct categories. The right page visually represents these categories: Immersiveness, Usability, and Cost vs. benefits.

The first category, Immersiveness, pertains to the technical aspects of the glove that account for the sensorial experience. The research reveals that customers currently perceive this technology as lacking sufficient quality. Specifically, the glove is deemed to lack precision, which implies required improvements in both hardware and software.

The second category, Usability, addresses the challenges that customers face in using the glove, despite SenseGlove's efforts to prioritize user-friendliness. This finding suggests that further enhancements are needed to ensure seamless and intuitive usability.

The third category, Costs vs. benefits, focuses on the cost-effectiveness of adopting the glove. Customers weigh the advantages offered by the glove against the associated costs, including both monetary expenses and the costs involved with integrating the product into their existing processes.

By clustering the insights into these three categories, a comprehensive understanding of the rationale behind not implementing the glove has been achieved.

1. No company priority

2. A cultural change is needed

3. The costs of the glove are high

4. Glove is bulky

5. The glove is hard to put on/not easy to wear

6. Gloves are fragile (stuff breaks easily)

7. Gloves are difficult to clean

8. Gloves does not add enough immersiveness

9. Controllers are easier to use

10. Difficult to integrate movement on little objects

11. Difficult to move around in large virtual spaces

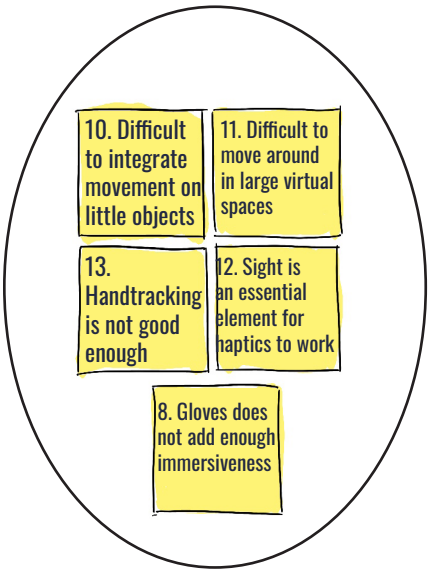
12. Sight is an essential element for haptics to work

13. Handtracking is not good enough

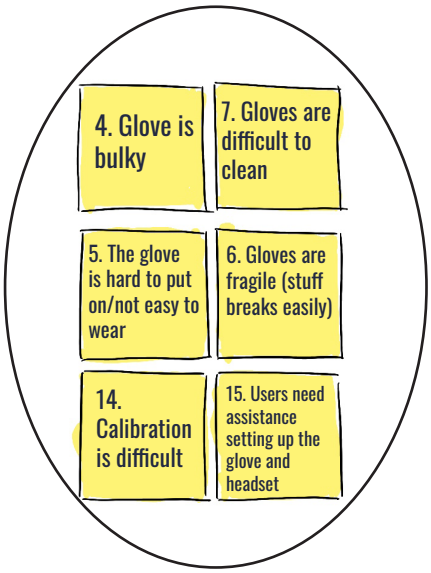
14. Calibration is difficult

15. Users need assistance setting up the glove and headset

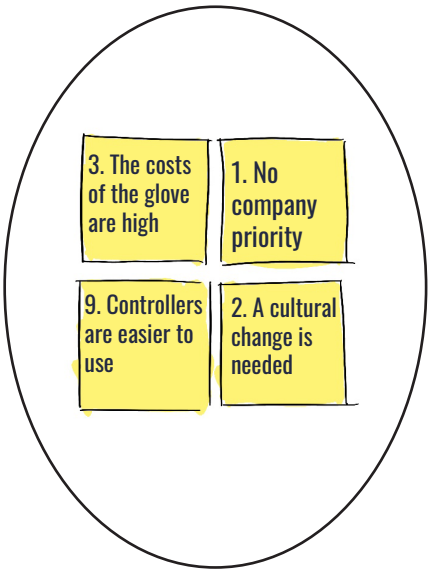
IMMERSIVENESS



USABILITY



COSTS VS BENEFITS



05

DESIGN / RECOMMENDATIONS.

Based on grounded theory, a comprehensive list of 15 arguments has been generated to explain why SG's customers are currently not implementing the product in their business processes. These issues can be organized across the categories of immersiveness, usability, and costs vs. benefits. As previously discussed in Chapter 3, the B2B market, similar to the consumer market, encounters challenges related to the MAYA principle. In the B2B context, it can be argued that the product is too advanced for the current state of the market.

As a final step in this graduation research, based on the insights described in previous chapters a future roadmap has been developed for SenseGlove.

Horizon 1: Take your customer by the hand and make the innovation acceptable

Horizon 2: Further develop your product and wait for the market to mature

Horizon 3: Enter the consumer market through a strong collaboration

https://www.apple.com/apple-vision-pro/

Horizon 1:

It has been concluded that the product does not fully meet customers' requirements at multiple levels, withholding them from implementing it. However, another significant reason for non-implementation is the amount of work that companies have to undertake before they can actually apply the product. Once a customer orders the Nova, the company itself is responsible for programming a virtual environment with training and ensuring that their staff learns to use the product.

This demands a lot for many companies and is a major reason why the Nova remains limited to the innovation department within companies, let alone being implemented in companies without an innovation department. SG can address this in the future by improving its products as the AR/VR market develops and becomes more widely accepted. This will further be elaborated on in step 2.

A good way for SG to generate traction at present, is by taking their customers by the hand. If SG wants its customers to use the Nova in operational departments during this phase, they will need to provide customization. This means engaging in conversations with their customers to assess the type of training they require and then delivering a ready-to-use product tailored to their customer's specific needs.

Horizon 2:

The second step of the roadmap recognizes that haptic technology is progressing ahead of the AR/VR market. Recent developments, such as the introduction of Apple Vision Pro, indicate the evolving nature of the market. However, experts suggest that the Vision Pro may not yet be suitable for mass consumption (Stokel-Walker, 2023). Thus, despite Apple's reputation for groundbreaking products, the Vision Pro may not currently meet the criteria for widespread adoption.

Nevertheless, this development represents another step in the right direction and is expected to contribute to the increased acceptance of VR/AR, including haptic technology. As these advancements unfold, it is my recommendation to SG that they continue to advance their product based on the 15 factors derived from the grounded theory analysis in Chapter 5. By addressing these aspects and aligning with customer demands, SG can persistently enhance their product, capitalizing on the evolving market landscape.

Horizon 3

For this concluding phase, we posit a scenario where AR/VR technology has achieved a breakthrough in the consumer market, witnessing widespread adoption among the general public. This opportune moment would pave the way for SenseGlove (SG) to venture into the consumer market, with online meetings emerging as a promising domain for exploration.

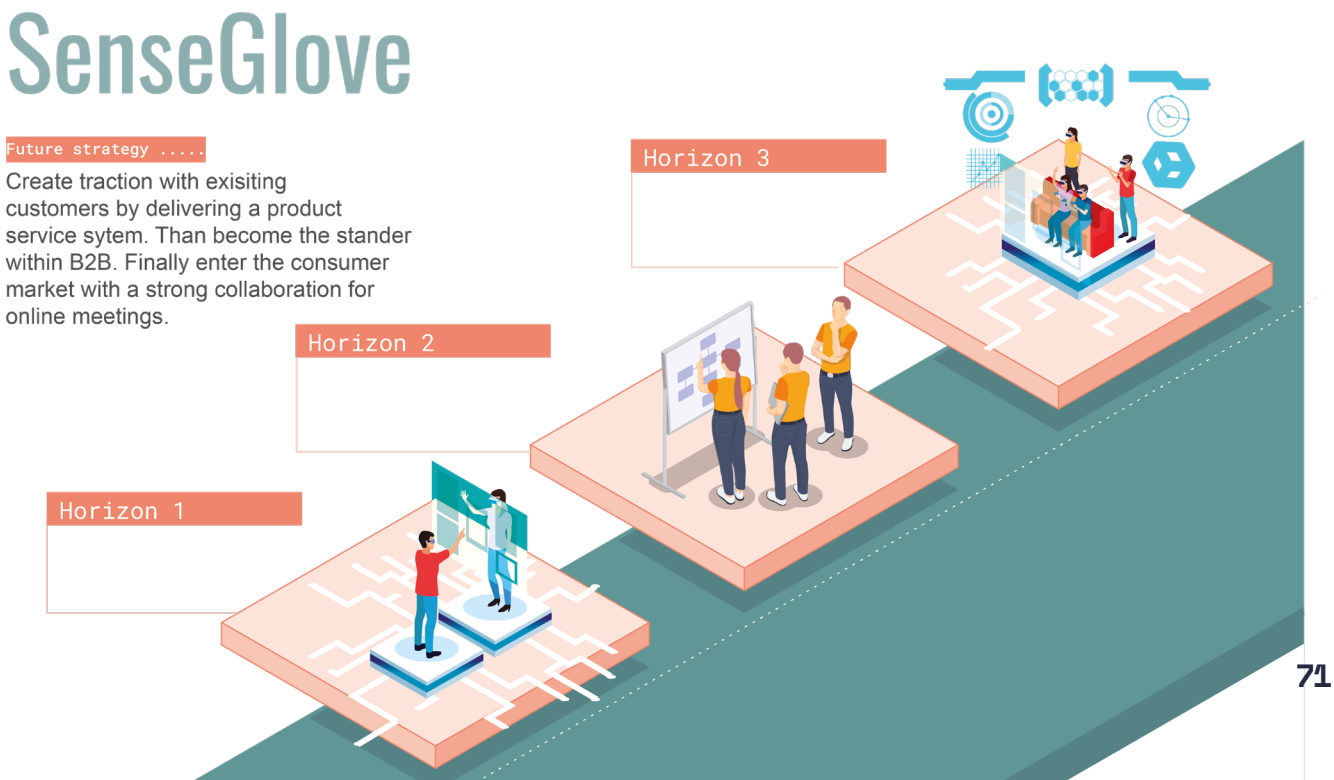
Nonetheless, two crucial elements require careful attention:

1. **Elevating the haptic capabilities of the glove to a higher standard, focusing on enhancing usability and immersiveness.**

2. **A novel approach to online meetings is required; one that effectively harnesses the potential of haptics andsurpassing the limitations of existing platforms such as Zoom, Microsoft Teams, or Google Meets at this moment.**

The attainment of the first objective lies within SG's purview, affording them control over the necessary advancements in their product's haptic features. However, the second objective lies beyond SG's primary sphere of expertise. To achieve a truly innovative paradigm for online meetings, SG would need to collaborate with established online meeting facilitators like Zoom, Microsoft Teams, or Google Meets.

This collaboration would foster the development of a new and transformative meeting experience, leveraging the full potential of haptic technology. By combining SG's expertise in haptics with the established platforms' online meeting capabilities, a synergy can be achieved, driving the creation of a novel meeting framework that capitalizes on the unique advantages of haptics.



06
REFLECTION.

DISCUSSION

This thesis report provides valuable insights into the integration of haptic technology in enterprise processes through the case study of SenseGlove. However, it is important to acknowledge certain limitations in the research methodology and participant selection. Firstly, the research utilized a qualitative method, which is effective for gaining insights but may not be considered a truth-seeking approach. The researcher acknowledges this own biases and acknowledges the possibility of being influenced by a specific topic of interest. While the qualitative approach provides valuable information and perspectives, it is essential to recognize that the findings are subjective and may not represent the entire range of perspectives.

Another limitation pertains to the selection of participants. The researcher relied on the clients of SenseGlove who responded to the initial email, potentially introducing a selection bias. This exclusion of clients who did not participate in the study could have led to incomplete or skewed findings. The reasons for non-participation by these clients remain unknown, and their perspectives may have provided valuable insights into the barriers and requirements for integrating haptic technology into enterprise processes.

Additionally, due to time limitations, the researcher was unable to validate the findings directly with the clients themselves. While the findings were validated with individuals within SenseGlove, it is important to note that direct validation with the clients would have strengthened the reliability and credibility of the research. The absence of this validation introduces the potential for misinterpretation or misrepresentation of the clients' perspectives.

Regarding future recommendations,the researcher suggests further investigation and detailing of the steps outlined in the roadmap. The advice for SenseGlove is to take the customer by the hand and develop a more comprehensive product service system. However, the specific actions needed to implement this approach are not thoroughly explored in the thesis. It is crucial for SenseGlove to delve into the details and work out a concrete plan before proceeding to the next stage.

Similarly, in the second step of the roadmap, the researcher suggests that SenseGlove should improve their product based on the 15 identified arguments. However, the thesis does not provide further research on the prioritization or the feasibility of these potential improvements. It is recommended that SenseGlove conduct further investigation to determine the easiest and most valuable arguments to address, in order to enhance their product effectively.

Lastly, the thesis proposes that SenseGlove should enter the consumer market when augmented reality (AR) and virtual reality (VR) are widely adopted. However, the exact timing and market conditions required for this entry are not extensively defined in the thesis. It is crucial for SenseGlove to define these parameters more precisely to develop a well-informed and effective strategy.

To conclude, while this thesis report offers valuable insights for SenseGlove's future direction and development, it is important to acknowledge the limitations in the research methodology, participant selection, and validation of findings. It is recommendable for SenseGlove to execute further investigation and detailing of the proposed steps in the roadmap, prioritizing the improvement of specific arguments based on thorough research, and defining the timing and market conditions for entering the consumer market. Addressing these limitations and recommendations will contribute to SenseGlove's ability to enhance their product offering, increase integration with enterprise clients, and potentially establish themselves as a leader in the haptic technology market.

PERSONAL REFLECTION

Writing this thesis has been a tremendous learning experience for me. Firstly, it allowed me to improve my academic writing skills, which will undoubtedly benefit me in future. Additionally, I gained valuable insights into the workings of tech startups and the intricacies involved in building a company from the ground up. Being able to observe these processes up close during my thesis was very enlightening. Witnessing how SensoGlove continuously improves their product and iterates on its development demonstrated the importance of persistence and adaptability in the world of startups. Moreover, I had the opportunity to see how they secured new capital and expanded their team, furthering their company's growth.

Furthermore, I discovered some new things about myself through this project. Initially, I realized that I struggled to work entirely independently, particularly during the initial stages of the project. I found that involving others and engaging in conversations served as a significant motivation for me to sustain progress and momentum in the project. As I reflect on this experience, I plan to seek out a working environment in the future where collaboration with others is encouraged, as it clearly enhances my own drive and productivity.

Another valuable lesson I learned was the ability to juggle multiple projects simultaneously. There were instances where external projects placed considerable pressure on me, making it challenging to balance my time effectively. However, as the thesis progressed, I developed the skill of multitasking and maintaining focus on the task at hand, even with various responsibilities demanding my attention. This newfound ability to compartmentalize and concentrate on individual tasks was a gratifying accomplishment.

The aspect of the project that I enjoyed most was engaging with clients and uncovering the underlying problems they faced. Through in-depth conversations and persistent questioning, I was able to delve into the deeper layers of their challenges. It was interesting to discover that the root causes of these problems often differed from my initial assumptions. This experience heightened my curiosity and further fueled my interest in the innovation process within companies. Finding solutions to improve innovation will undoubtedly be a focus of mine as I progress in my career.

In conclusion, undertaking this thesis provided me with a multitude of learning opportunities. Not only did I enhance my academic skills, I also gained valuable insights into the inner workings of tech startups, discovered more about my own working preferences, improved my multitasking abilities, and developed a strong interest in fostering innovation within companies. These newfound understandings will undoubtedly guide me as I embark on the next stage of my career, allowing me to pursue my passion for innovation and make meaningful contributions in the years to come.

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08
APPENDICES.

APPENDIX 1: INTERVIEW GUIDE

Interview guide input Nova

1. Could I record this meeting to later analyze it?
2. Some topics I would like to discuss

- Application of the Nova?
- Feedback on customer service
- Feedback on hardware
- Feedback on software
- Integrating haptics in your company processes

What is your function within [company]?

Application of the Nova? (5 min)
- What pushed you to buy a Nova?
- Was there a specific use case you are using the glove for?
- Have you performed this use case?
- Are you planning on having other applications with the Nova in the future?
- What steps your company took after purchasing the Nova?

Feedback on customer service (8 min)
- How did you find SenseGlove?
- How was your experience in getting in touch with SenseGlove

Feedback on software (8 min)
- Do you program the software internally?
- How was your experience integrating the glove in your use case?
- Demo? (Do you know about our demo's?)
- How do you feel about the connectivity of the Nova?
- What is your opinion on the ease of use of the glove?

Feedback on hardware (8 min)
- How was your experience with the haptic feedback of the glove?
- How do you feel about the overall design of the glove?

Integrating haptics in your company processes
- Is your company planning to integrate haptics into its company processes?
- Why (not)?
- Why haven't you placed a second order yet?

Is SenseGlove the right partner for you?

General
- Can we contact you in the future for further research questions?
- If you have other questions please contact us. (Via sales or support ticket on the website)

Extra questions.

Do you currently train people in VR?
How do you evaluate hardware, what do you test it against?
How do you currently test hardware for your VR training projects?
What are the key performance indicators (KPIs) you use to evaluate hardware performance?
What are your plans for scaling your VR training program?
How do you see the SenseGlove Nova fitting into your current VR training workflow?
Are there any specific features or functionality that you're looking for in a VR training hardware solution?

Time-line

Customer Journey

- Purchase etc.

Interview technique

- Ask questions about nonverbal communication (Why are you laughing?)

APPENDIX 2: SWOT RAW DATA

Strengths

- SG is the only company that currently offers a glove with force-feedback, vibrotactile feedback, and wireless connectivity that is still affordable. Additionally, they have the most user-friendly glove on the market. - PM1
- The employees at SG have high morale and can perform well even under pressure.
- SG uses a flexible working method, utilizing a two-week scrum cycle that allows them to quickly test and integrate new features into their product and change their focus every two weeks. - persoon
- The team at SG is diverse and highly skilled, which allows them to build their product in-house from start to finish.
- SG has a lot of innovation power and can quickly implement new ideas due to their small but efficient team.
- The product has many software integrations, making it compatible with different software programs such as Unity, C++ API, and Unreal Engine.
- SG uses a "pull production strategy," meaning they maintain just enough stock to deliver during peak demand while minimizing rework when production goes wrong. They can produce around 5 sets per week, and their stock is around 50 sets (as of 2022).
- SG has a ROS plug-in for telerobotics, which is widely used in the industry.
- SG is located on campus, which enables them to easily attract students to work on glove assembly during peak demand periods. They can find new assembly workers within a week.
- They have a strong connection to the TU, making it easy for SG to find new talent to work for them.
- SG has a head start in the market, with only HaptX as their main competitor. However, HaptX's glove costs around 80k, and Manus does not offer force feedback, while Dexmo's glove costs €12,000.
- SenseGlove has relatively more users than their competitors, resulting in more user feedback. Although HaptX may have more resources, they sell fewer products and thus receive less feedback.
- SG has intellectual property on some of the software and hardware parts of their product. For more information, you can ask Johannes.

SG is driven to create a product that fits the market, while other tech startups often focus on creating the most advanced product possible.

Weaknesses

- Because each employee within the development team has their own expertise, the company is highly dependent on a few individuals.
- The company has a relatively large stock of both parts and end products, which poses some risks.
- Due to the low production volumes, all gloves are assembled in-house, which can lead to small mistakes during assembly. This results in a relatively high amount of time spent on after-sales support. While this is not a significant issue in a small B2B market, it could become a problem in a larger B2C market.
- Assembling the product by hand in-house requires highly accurate and dedicated workers in the assembly department to minimize mistakes. Unfortunately, not everyone in the assembly department is focused on quality, resulting in occasional errors.
- SG makes numerous iterations of its product during the lifetime of one version (e.g., v1.1, v1.2), leading to more mistakes in the production process. Also, due to these changes, the final product always retains some prototype elements.
- Clients compare the gloves with existing headsets that are far more developed, resulting in some disappointment because of too high expectations. They purchase a more expensive "add on" that is of lower quality than the main product (the HMD).
- After-sales services account for a significant amount of time, as around 30% of clients return with questions related to installing the glove and developing the software.
- Using a pull strategy is risky, as SG may not be able to meet an unexpectedly high demand, and unexpected delays in the supply of parts can cause problems for SG.
- SG does not have a clear vision for the future, and sometimes operations within the company are messy because not everyone knows what is expected of them (e.g., it was only clear what the new features for the Nova 2 would be at a very late stage).
- Getting the quality of the end product to a high level is a long and slow process, as SG is a small team/company.
- The product is complicated, and many aspects of the product are dependent on each other, making it challenging to make significant strides in developing the product further.
- The force feedback system currently used by SG is dependent on mechanical components, making it difficult to make the product smaller and lighter while still being affordable.
- SG's product focuses solely on haptics, whereas other products use haptics to improve the overall product. The scope of applications is very broad, which may reduce the product's value.
- Communication between management and development is not always optimal, and there are general communication issues within SG.
- Due to a limited budget, everything happens in-house, which sometimes results in too few people working on a project, causing unnecessary delays.
- SG does not like to outsource tasks, partly due to bad experiences in the past.

- The force feedback system is only passive and not active.
- Marketing for the product is challenging because people need to experience it to understand how to use it properly.
- Putting the gloves on and off is still quite difficult at present.
- Currently, SG works with one large R&D team, which may need to be split up if the company wants to grow in the future.
- In-house production is limited to a certain volume.
- Growing the company is challenging because current clients need to innovate their company to use SG's product on a daily basis. The Nova needs to move from the innovation department to the operational department, which requires a behavioral change within the companies of our clients.
- The market is still in the early innovator phase.
- SG is a small company and is dependent on a few key employees with specialized knowledge. Losing any of these individuals would have significant consequences.
- Innovating soo much makes it difficult to prioritize task

Opportunities

- The current market for virtual force feedback gloves is small and has little competition.
- To finance development, SG can use the WBSO-regeling (Wet Bevordering Speur- en Ontwikkelingswerk). https://www.rvo.nl/subsidies-financiering/wbso
- SG engages in synergetic development, as many companies are interested in having things researched by SG that also benefits SG as a company (for example, the Neom project).
- The market for XR (AR/VR) is growing, which is exactly the field where SG operates. (See market growth figures.)
- There is not yet a B2C market for XR haptic devices, but this may develop in the near future.
- Haptic gloves could be a huge addition to the gaming industry.
- If SG faces more serious competition in the future, there will be more stimulation to improve their product. They will also know who they are competing with.
- The market for VR headsets is growing, and the steep part of the curve is still expected to come. SG could benefit from this growth.
- SG is doing great at what they do, so being bought by a bigger company would be an option.
- Currently, the force feedback system is only being used for hands, but applying it to other body parts is also possible. All of SG's technology is integrated into one product, but this could be multiple products in the future.
- Integrating the SG software with VR operating systems like SteamVR, Oculus, or Meta (difficult because Oculus and Meta are not open source). SteamVR doesn't support force feedback.
- Making VR interactions more realistic.
- People are working more from home. Using VR and haptics in this at-home working environment could be an opportunity.
- Telerobotics market: Robots are becoming more remote and are being used more and more.

- VR headsets are getting better and more affordable. When the consumer market for VR headsets grows, it might be valuable to have a haptic device as an add-on product.
- Creating more intellectual property (SG already spends relatively much money on this).
- There will be a market with consumers interacting in 3D environments in the near future.
- For the B2C market, multinationals are investing large amounts of money. Within the medical market, there are still many opportunities. (Johannes)

Threats

- If big players in the market, such as Apple, Microsoft or Meta, start developing haptic wearables, SG is likely to lose the race in the B2C market. Big companies have the possibility to penetrate the market with big capital. However, in the B2B market, that doesn't have to be the case because SG already has a leadership position in the market with relatively many clients. Meta already has a team working on haptic hand devices (inside information): https://m.facebook.com/RealityLabs/videos/380447450537915/
- Consumers (B2C) are less educated on what haptics are, and they will probably have too high expectations. In B2B, this is already a problem.
- All activity within SG is hand-based, which can be a limitation since there are many sectors where there is no demand for hand-based haptics.
- SG is highly dependent on the XR-headset market.
- There is a shortage of electronic parts, such as solenoids (motor), mostly due to a shortage of parts being used in the automotive industry.
- If VR does not become a big thing in the "at-home" market, SG will have little right to exist in the B2C market.
- The development of telerobotics is stuck in the research phase.
- A new economic crisis could impact SG's growth.
- The potential competition's power is a concern, as Meta has their "moonshot" project (which they are probably not going to bring to market).
- Big tech companies may come out with a better product than SG's.
- SG does not have access to the data of HMDs. There is no access to the front-facing cameras, making it impossible to connect an SG product.

Other

- Thought-Leadership within the current market (Gijs)
- Flexible and able to adapt quickly to market demand (because we are relatively small. There is little overlap in the development team, which allows everyone to work independently on their expertise.
- We are working on an interesting and attractive technology, which is why people come to work in the development team at SG through internships. This ensures that we know exactly who we are hiring.
- We are good at wearable haptics. We have a cheap scalable solution that works.
- The product is not mature enough at the moment to prevent errors in production. You really have to assemble it with feeling.

APPENDIX 5: INTERVIEW BOB METZ

Waarom zijn binnen corporates na corona toch weer meetings offline

- Deden jullie bij Kearney online meetings voor corona?

Ja, maar er heeft een verandering plaats gevonden.
Een proposal (klus verkopen) en pitches doen we ook na corona online
Bij slecht nieuws gesprekken is het fijn om daar te zijn en 2/3 dagen de tijd te hebben. Dat is lastig.

In het echt bouw je een band op met je klant (slap lullen). Die relatie help later in het process vaak. Inhoudelijk kan alles gewoon online

8 weken programma met Pon in NL. Maandag tot donderdag kwamen gasten over uit Duistland en Oostrijk om 1 dag bij de klant te zijn. Eerste 4/5 weken hebben we dat gedaan, maar daarna was het ook helemaal prima om het online te doen. Toch is offline wel makkelijker, maar het kan online.

Projecten die ik volledig online heb gedaan: 'project heb ik gedaan maar de mensen ben ik weer kwijt'

Er zijn mensen die hardop zeggen dat ze wel consultant willen zijn, maar niet willen vliegen. Aan de andere kant zijn er ook mensen die het fijn vinden in hotels, lekker eten en nieuwe plekken.

Voor corona vonden ook klanten het normaal

- Hoeveel van je meetings op werk zijn op dit moment online vs offline

Tussen de 6 en 10 meetings per dag. Die zijn allemaal online nu in Mexico. Maar daarvoor zat ik in NL.

- Wat zijn de verschillende soorten meetings die je hebt.

Interne team meetings
Office meetings (elke twee weken met hele kantoor)
Office meetings globaal
Klant meetings
- Pitches
- Wekelijkse workflow meetings
- Steering comité meetings

Extern

APPENDIX 6: A DAY AT THE PRODUCTION DEPARTMENT

To gain deeper insights into the internal components and assembly process of the Nova, I had the opportunity to shadow Fernando, a member of the production department, for a day. Together, we went through each step of the production process, providing me with a comprehensive understanding of the various components housed within the Nova. I observed firsthand the limited internal space available to accommodate these parts, leading me to realize that incorporating additional functionality into the glove would have significant implications for its size.

During my conversation with Fernando, he mentioned that the production process still encounters many errors. This is primarily attributed to the manual labor involved and the frequent release of new versions of the Nova (such as V1.0, 1.2, etc.). The constant updates increase the likelihood of mistakes being made. However, a significant advantage is that it is easy for SG to make adjustments to their products and incorporate them directly into the production process. SG will lose this advantage when professionalizing their production process.

Currently, SG has sold approximately 250 to 300 sets of the Nova. While sales and production of the existing Nova system continue, SG is concurrently working on the development of the Nova 2.0. Since this development began towards the end of this thesis, it will not be further discussed in this report.

APPENDIX 7: HAPTIC TECHNOLOGY

Haptic technology can be defined as technology that interacts with a user through their sense of touch (Rubin, 2020). The haptics term comes from the Greek “haptikos” meaning “concerning the sense of touch” (Interhaptics, 2023). This technology is still going through a lot of development and within the industry there are different terms being used to describe the same sort of haptic feedback. This paragraph uses the example of holding a coffee cup to elaborate on the terminology that will be used in this thesis.
Touch is one of the five senses but actually exists out of several different senses combined (Poole, 2021). There are four different kinds of 'sensory channels' through which a human can interact with haptic technology: tactile-, thermal-, force-(active passive) and vibrotactile feedback.

Imagine holding a cup of coffee...

Tactile feedback is about patterns of pressure on the surface of your skin. It enables you to feel the fine shapes and textures of an object. For example the smoothness of the coffeecup you are holding in your hand. Tactile feedback is probably the most difficult kind of feedback to get right in a haptic device because it requires very specific pressure points to the skin in order to feel realistic.

Thermal feedback is much simpler. When holding the coffee cup you can feel the warmth coming from the cup. It is not just that simple however. Objects with the same absolute temperature can feel like their temperatures are different. This is because the human skin does not only sense absolute temperatures but also flow of heat energy. This is dependent on how well a material conducts heat (thermal conductivity) (Rubin, 2018). If the coffee cup would be made from steel instead of paper it would feel much warmer while the absolute temperature is actually the same.

Force feedback (active/passive) enables you to hold the coffee cup and not squeeze right through it. It is the resistance that the cup exerts on your fingers. Feeling the resistance of an object by having your fingers blocked is an example of passive force feedback. If the object were able to expand, like a balloon, your fingers would be pushed away which would be an example of active force feedback. Then finally force feedback is also about feeling the weight of the cup (Rubin, 2018). When a force is applied to an entire limb as is the case in this situation the term kinesthetic feedback is often used.

Vibrotactile feedback doesn't apply to the coffeecup you are holding but is already being applied in a lot of tech devices we see today. Examples are the buzz in your smartphone and the rumble of a game controller.

These four sensory channels combined is what we refer to as the human sense of touch. If all four were to be integrated in a haptic-glove and had the same accuracy as the human hand a human being would not be able to feel the difference between a real and a digital object. Of Course this is not technically achievable now and will probably never be achievable.

Besides these four haptic technologies there are three other ways of giving haptic feedback, electro-haptic stimulation and ultrasound tactile feedback. electro-haptic stimulation uses electric stimulation to stimulate the nerve endings to trick the user's brain into feeling contact. Ultrasonic haptic feedback uses ultrasound to create a disturbance in the air that the user can feel when they pass their skin across it. In this case the user does not need to wear any haptic device. These two forms of haptic-feedback are not relevant for the rest of my thesis because both technologies are in a very early stage and not applicable to wearable haptic devices.

Finally there is hand and finger tracking. This is not a form of giving haptic feedback but it allows to determine where a user's hand and fingers are in space. This information is crucial to activate the different haptic senses in a haptic device at the right moment. Getting the tracking right is a must to create an immersive* experience and thus very relevant in relation to SenseGlove their products. Of Course these terms specifically are only relevant for haptic Gloves. In theory a haptic shoe would need feet and toe tracking.

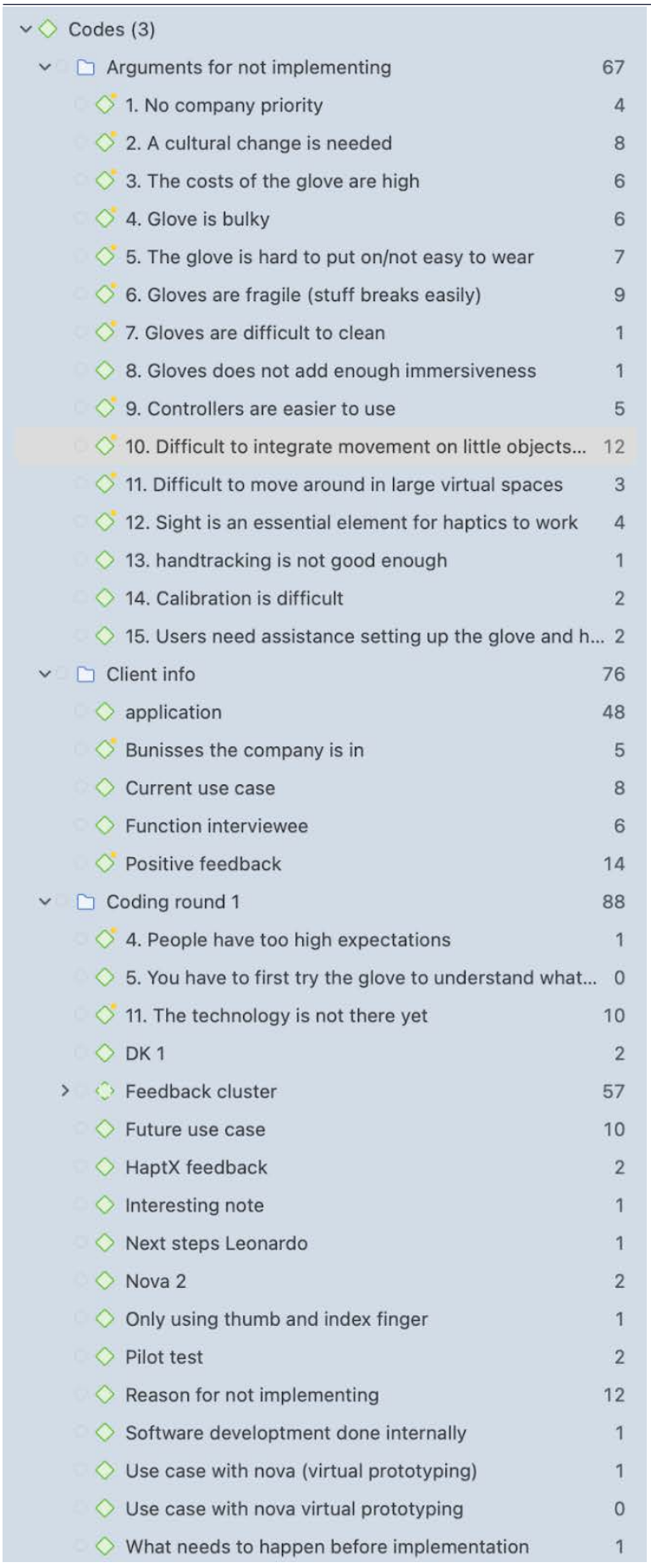
** In virtual reality, immersion refers to the feeling of being fully present in a digital environment.*

APPENDIX 8: COMPETITION OVERVIEW

Haptic gloves

Item	Image	Company	Country
CyberGlove II		CyberGlove Syste...	USA
CyberGlove III		CyberGlove Syste...	USA
CyberTouch I		CyberGlove Syste...	USA
CyberTouch II		CyberGlove Syste...	USA
CyberGrasp		CyberGlove Syste...	USA
HaptX Gloves DK1		HaptX	USA
HaptX Gloves DK2		HaptX	USA
Dexmo Developer ...		Dexta Robotics	China
Nova		SenseGlove	Netherlands
SenseGlove DK1		SenseGlove	Netherlands
SenseGlove DK1 w....		SenseGlove	Netherlands
Prime II		Manus	Netherlands
Prime II Haptic		Manus	Netherlands
VRGluv		VRGluv	USA
Cynteract		Cynteract	Germany
Forte Data Glove		Bebop Sensors	USA
Hi5 VR Glove		Noitom	China
Sensorial XR		NeuroDigital Tech..	Spain
Senso Glove DK3		Senso Devices Inc.	USA
VMG 35 Haptic		Virtual Motion Labs	USA
Maestro		Contact CI	USA
Teslasuit Glove		VR Electronics Ltd	UK
Tactglove		b-haptics	South Korea
Reality Labs Resear...		Meta	USA

APPENDIX 9: COMPLETE CODE BOOK ATLAS.TI



APPENDIX 10: INTERVIEW GIJS ABOUT ONLINE MEETINGS

Gijs den Butter - Chief Product Officer & Co-Founder

25-02-2022

Quotes from the interview:

"I anticipate that physical digital meetings will be the initial application of haptics within the consumer market in Phase 5."

5 phase future strategy SG
They have defined 5 different phases between now and 2030 and describe how their product and market will change during these phases (SenseGlove strategy, 2021).

Now - 2022 Increasing adoption of virtual training in enterprise market
Phase 1 - 2023 Low-cost pass-through VR for brought applications.
Which phases can we distinguish?
What does this mean for SG?
Phase 2 - 2023/2024 Growth of hololens-like optical AR products with lower price (volume) and ensure that these products are used for more (technical) applications.
(Pass trough AR will eventually be overtaken by optical AR. Purely because optical AR can be embodied smaller. In the beginning, these will coexist.)
Phase 3 - 2024 New generation AR glasses for the enterprise market that are still too expensive for consumers but have a normal form factor (normal glasses-like/fashionable) ready for the white collar enterprise market
Phase 4 - 2025-2027 Enterprise AR market for collaboration market, meetings with Avatars, multiplayer design/collaboration. From this market the AR glasses will be taken home and consumer applications will arise. (prosumers)
Phase 5 - 2027-2030 Consumer haptics market will start as:
Major consumer brand with 3D AR glasses/lens/optical device enters the market
After introduction, other brands will follow, the price drops and adjacent products will be added.
2 years after the first introduction of consumer 3D AR glasses/device, a haptic input device must be ready for sale

2022 Sell, Produce Nova & Create POC's with AR
2023-2024start sales for AR design applications with Nova and training where environment doesn't matter. Possibly with pass through
Cost Nova to 650 euros in 2024, sales price to 2500 euros with the right perceived fidelity for skilled workers.
Nova Pro with higher perceived fidelity next to a new input device, to test perceived realism and to broaden the market for (workshop) skilled training and possibly use it as control (telerobotics).
2025 haptic input device should fit in a pocket and be continuously wearable for enterprise market: spatial collaboration for office workers.
Renewed version of a NOVA Pro with contact haptics (skin deformation) and accelerating masses for weight simulation.
2027 first consumer device conceived in terms of price and portability. Introductory price below 1000 USD.
2029 consumer version under USD 500

34344A

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A5A299

APPENDIX 12: PROJECT BRIEF

Designing and evaluating a new use case for SenseGlove Nova — project title

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

start date 11 - 04 - 2022 — 26 - 08 - 2022 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

Sense Glove (SG) allows to feel shapes, textures, stiffness, impacts and resistance of any virtual object, so you can experience digital worlds, through intuitive real-world behavior (SenseGlove, 2022). Their latest glove 'The Nova' is now mainly being used in a B2B context for training purposes. SG is mostly active in the automotive business where employees are being trained in a virtual environment on how to assemble cars. However for SG there are countless of opportunities for use cases in different sectors. Examples of possible future sectors are healthcare and first responders. Besides training SG also uses their glove for digital prototyping, marketing and research purposes.

Before the Nova SG had already developed a previous glove called The Development Kit 1 (DK1). This model gives more accurate finger tracking and force feedback compared to the Nova but is also less user friendly. For that reason this model has reached its end of life. SG is also interested in designing new products. Right now they are looking into telerobotics which is an area of robotics concerned with the control of semi-autonomous robots from a distance.

SG's vision is to have their technology become the mouse and keyboard of the future. For this reason they want to enter the consumer market within 5 to 10 years. However, an ecosystem within which consumers can use the SG Nova is not existing at this moment. Only within a B2B context there is compatible software.

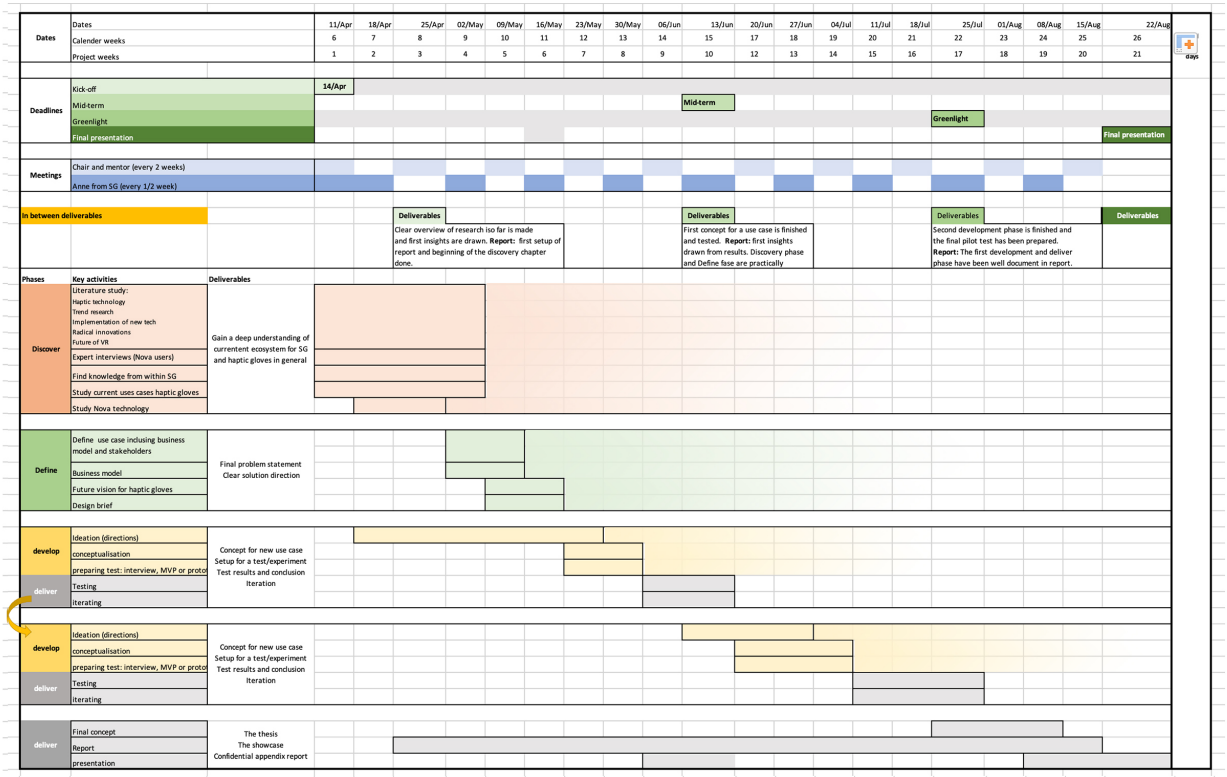
My goal during this project is to make the step for SG to enter the consumer market smaller. I will do so by exploring possible new use cases for the SG Nova and test the most promising use case by doing one or more pilot tests. This will give SG new information on how their technology can be used in the future. Because entering the consumer market is still in the far future for SG I will design a use case within a B2B context during this project.

space available for images / figures on next page

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 11 - 4 - 2022 26 - 8 - 2022 end date



The project will take place during a period of 20 weeks. Each week I will spend 40 hours on the project. I plan to meet with my mentor, chair and supervisor every two weeks. Also half way through my project I planned a break of one week. This week I will use to take some time off, but also provides me buffer during the project.

I used the double diamond method by The British Design Council to plan my graduation project. This process has a discover, define, develop and deliver phase.

The discover phase will help me to understand rather than to simply assume things. I will explore the subject of haptic gloves and all relevant related subjects. I will do so by doing a literature study and by talking to people related to the subject. By doing so I hope to gain a deeper understanding of Haptic technology and what this technology might be used for in the future.

In the define phase I will use the insights found during the discovery phase to define a direction to head in and a design brief. During the development phase I will diverge and come up with different potential new use cases for The Nova. Than in the deliver phase I will test the most promising concept and iterate on it.

A detailed planning can be found in the gannt chart above. I am taking an agile approach to this project which means that the process will be iterative. For that reason I want to go through the whole process once before the mid-term meeting and then repeat the develop and deliver phase to come to a final concept.

Initials & Name M.P. van de Ven Student number 4447417

Title of Project Designing and evaluating a new use case for SenseGlove Nova

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

For this project I have decided to focus on the SG Nova because it is on the market right now enabling me to do testing with the actual product. Also because I want to be able to do testing within the period of 20 weeks I already made this decision to narrow down my scope.

The problem SG encounters is that at this point the use cases for The Nova are limited. By designing and evaluating a new use case I want to broaden the ecosystem within which it can be used. An important note is that the current use cases of SenseGlove are more a proof of concept than an application of their haptic glove that is ready to be used in the real world.

Right now SG is mostly active in the automotive field however they are interested in other use cases as well. Their vision is to make SG the mouse and keyboard of the future. The goals is to enter the consumer market within 5 to 10 years. An innovative new use case will bring SG a step closer to reaching this goal. However besides designing this new use case I also want to use my insight to create a vision on how I think this new technology can be adapted by the consumer market.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

During this project I will research the current ecosystem of haptic gloves and potential new use cases. With this knowledge I am hoping to find a new use case. I want to then evaluate its potential by doing (a) pilot test (s) and use the results to iterate and come with a final proposition.

In order to find a new use case for SG I will first need to develop more on the subject. I will do so by researching literature and interview experts. The literature I want to study will be on the technology of haptic feedback and VR; The future of these technologies and on implementation of new technology/radical innovation in general. Examples of experts I am planning to contact are clients and software developers that have used the nova. Besides I will talk to people within SG about their thoughts on the product and hopefully I will also be able to experience myself what it is like to use their technology. I will also analyze existing use cases from both SenseGlove and competitors.

With this knowledge I will looking into sectors where use cases with the nova might be valuable. The next step would be to develop a concept for a new use case. By doing a pilot test I want to than validate whether the use case is valuable to all stakeholders.

At the end of my project I aim to deliver a concept for a new use case that is proven to be valuable for both SG an the user(s). I will formulate what the virtual environment looks like, how the user behaves within this environment and what feedback is expected from the Nova. Possibly this will also lead to recommendation on how to improve the Nova in the future to better suit the use case.

Initials & Name M.P. van de Ven Student number 4447417

Title of Project Designing and evaluating a new use case for SenseGlove Nova

introduction (continued): space for images

image / figure 1: The Nova

image / figure 2: The Nova being used for assembly training

Initials & Name M.P. van de Ven Student number 4447417

Title of Project Designing and evaluating a new use case for SenseGlove Nova

Designing and evaluating a new use case for SenseGlove Nova — project title

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Sense Glove (SG) allows to feel shapes, textures, stiffness, impacts and resistance of any virtual object, so you can experience digital worlds, through intuitive real-world behavior (SenseGlove, 2022). Their latest glove 'The Nova' is now mainly being used in a B2B context for training purposes. SG is mostly active in the automotive business where employees are being trained in a virtual environment on how to assemble cars. However for SG there are countless of opportunities for use cases in different sectors. Examples of possible future sectors are healthcare and first responders. Besides training SG also uses their glove for digital prototyping, marketing and research purposes.

Before the Nova SG had already developed a previous glove called The Development Kit 1 (DK1). This model gives more accurate finger tracking and force feedback compared to the Nova but is also less user friendly. For that reason this model has reached its end of life. SG is also interested in designing new products. Right now they are looking into telerobotics which is an area of robotics concerned with the control of semi-autonomous robots from a distance.

SG's vision is to have their technology become the mouse and keyboard of the future. For this reason they want to enter the consumer market within 5 to 10 years. However, an ecosystem within which consumers can use the SG Nova is not existing at this moment. Only within a B2B context there is compatible software.

My goal during this project is to make the step for SG to enter the consumer market smaller. I will do so by exploring possible new use cases for the SG Nova and test the most promising use case by doing one or more pilot tests. This will give SG new information on how their technology can be used in the future. Because entering the consumer market is still in the far future for SG I will design a use case within a B2B context during this project.

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