Appendix 1 :Assignment

MEDISIGN GRADUATION OPPORTUNITY
WORK-RELATED MUSCULOSKELETAL INJURIES

The Dutch Society for Ophthalmology (in Dutch: Nederlands Oogheelkundig Gezelschap (NOG), www.oogheelkunde.org) is an organization of ophthalmologists in The Netherlands. The NOG wants to start a graduation project with the Faculty of Industrial Design Engineering with a focus on prevention of work-related musculoskeletal injuries.

A survey revealed that about 60% of ophthalmologists suffer from problems in the neck, shoulders or lower back such as hernia or osteoarthritis. Besides physical complaints they also have to deal with high stress levels.

The working posture is not optimal due to the medical equipment design like the slit lamp, which is a frequently used part of the equipment. The design of the devices should fit both the ophthalmologists and the patients (anthropometrics), and its placement should be taken into consideration when designing the layout of a consulting room. Next to physical human factors, this can also include organizational factors. Besides these aspects, instructions for the users about healthy working postures and behavior should also be considered.

This graduation project can be seen as one of the first steps to improving the work situation of ophthalmologists. The project includes getting an overview of the characteristics around the activities of an ophthalmologist in different hospitals and of the role of design in their work, and defining possible interventions including product design.

The section Applied Ergonomics and Design is involved in this graduation project. This project is a perfect match in case you are doing the Medisign specialization. Please contact Gonny Hoekstra for further information about the assignment.

And please don't hesitate to contact the stakeholder as well (Daphne Albers from the NOG).

Contact information NOG

NEDERLANDS
OOGHEELKUNDIG
GEZELSCHAP

Daphne Albers
Advisor

Appendix 2 : Graduation proposal

DESIGN FOR our future

TUDelft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT
Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME
Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy". Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Michon
initials: Y given name: Yan
student number:
street & no.:
zipcode & city:
country:
phone:
email:

Your master programme (only select the options that apply to you):
IDE master(s): [x] IPD [ ] DfI [ ] SPD
2nd non-IDE master:
individual programme: - - (give date of approval)
honours programme: [ ] Honours Programme Master
specialisation / annotation: [ ] Medisign
[ ] Tech. in Sustainable Design
[ ] Entrepeneurship

SUPERVISORY TEAM **
Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: Prof. dr. Stappers, P.J. dept. / section: HCD DCC
** mentor: Ir. eur.erg. Hoekstra, G.P.M. dept. / section: HCD AED
2nd mentor: Ir. Daphne Albers
organisation: NOG (Nederlands Oogheelkundig Gezelschap)
city: Utrecht country: Netherlands

comments (optional)

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

TU Delft

Procedural Checks - IDE Master Graduation

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair Prof. dr. Stappers, P.J. date - - signature

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair. The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: ______ EC

Of which, taking the conditional requirements into account, can be part of the exam programme ______ EC

List of electives obtained before the third semester without approval of the BoE

YES all 1st year master courses passed

NO missing 1st year master courses are:

name ______ date - - signature ______

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **. Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: APPROVED NOT APPROVED

Procedure: APPROVED NOT APPROVED

comments

name ______ date - - signature ______

Personal Project Brief - IDE Master Graduation

Improving the Ergonomic working conditions of Ophthalmologists — 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 17 - 11 - 2023 12 - 04 - 2024 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, ...).

Ophthalmologists are physicians with the subspecialty training in medical and surgical eye care. They are different to Opticians, whom are trained to design, verify and fit eyeglass lenses and frames, contact lenses, and other devices to correct eyesight. Ophthalmologists differ in that they diagnose and treat all eye diseases, performs eye surgery and prescribe medication to correct vision problems. Ophthalmologists often cope with musculoskeletal injuries in the wrists and hands as well as the neck and shoulders, caused by the many small, repeated movements they have to make to adjust their equipment to different patients, as well as suboptimal posture while doing so. The goal for this project is to reduce these types of injuries.

The stakeholders in this project are:
- NOG (Nederlands Oogheelkundig Gezelschap / Dutch Ophthalmological Society). The NOG has been the Dutch scientific association of ophthalmologists since 1892. Through the NOG, they uphold the quality of eye care. In addition, the NOG facilitates and supports ophthalmologists in the performance of their profession. An Opportunity related to NOG are their Connections with many medical professionals in the country. A limitation in the context of this project is their impartiality towards the industry. To guarantee the best support to their members, they don't want to side with any producers of Medical or other equipment. This could be a limiting factor for me as a designer.

- Ophthalmologists are the end users of the solution that is to be designed in this project. They are the problem owners and they experience the musculoskeletal injuries in question. An opportunity for them personally, is a chance at better working conditions in the long term. Furthermore, despite having a major say in the purchasing of medical equipment, they work in a context that is partly determined by the possibilities of the clinic or hospital in which they work. Other interests and conditions of the organization they work within also play a role in the choice of equipment. This can be a limiting factor for them.

- Medical institutions. Ophthalmologist generally work in either a specific department of a hospital or in independent treatment clinics. An opportunity for these institutions is the improvement of employee satisfaction and efficacy by improving their working conditions and comfort through this project. The institutions are however naturally limited by their budget and the size of investment necessary to realise said improvement.

- Producers of Ophthalmology equipment. An opportunity for this party is better user satisfaction through the development of a more ergonomic use scenario that will be better suited to the needs of their users. Their limitation however is tradition. According to my pre-research with MID (medical technicians in the Rotterdam Eye hospital), producers of ophthalmology equipment can be rather conservative when it comes to innovation. This could be a limiting factor for me as a designer.

- Me. My opportunity within project is to learn more about the design practice, the subspeciality of Medisign and my personal professional goals. I am limited in this by available resources, other stakeholders' preferences and time.

- Patients. In the end, patient satisfaction is paramount. Whatever changes are made to the Ophthalmology practice may never reduce the quality of medical care.

space available for images / figures on next page

Personal Project Brief - IDE Master Graduation

TU Delft

introduction (continued): space for images

image / figure 1: The Splitlamp, the most commonly used piece of equipment in an Opthalmologist's practice

TO PLACE YOUR IMAGE IN THIS AREA:

- SAVE THIS DOCUMENT TO YOUR COMPUTER AND OPEN IT IN ADOBE READER
- CLICK AREA TO PLACE IMAGE / FIGURE

PLEASE NOTE:

- IMAGE WILL SCALE TO FIT AUTOMATICALLY
- NATIVE IMAGE RATIO IS 16:10
- IF YOU EXPERIENCE PROBLEMS IN UPLOADING, COVERT IMAGE TO PDF AND TRY AGAIN

image / figure 2:

Initials & Name Y Michon Student number

Title of Project Improving the Ergonomic working conditions of Ophthalmologists

Personal Project Brief - IDE Master Graduation

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.

Ophthalmologists often cope with long-term musculoskeletal injuries in the wrists and hands as well as the neck and shoulders. The goal for this project is to reduce these types of injuries.

For the design scope, I will (initially) only address the needs of ophthalmologists. While their equipment overlaps with that of opticians and optometrists, I will limit myself to the needs of ophthalmologists in favour of keeping the problem manageable in the available time. If the final results apply more broadly in the end, this will be a bonus.

I will (initially) only focus on the Split lamp. Ophthalmologists spend the vast majority of their time using this device, as shown in the picture above. Ergonomic improvements to this device will have a significant impact on reducing musculoskeletal injuries in the field.

To properly design for this scope, it is useful to do prelimenary research with a slighlty larger scope. This is to prevent losing out on useful insights, that could be lost with an overly small focus at the start. For this reason I will also consider the broader work scenario of the ophthalmologist in the research stage.

I will (initially) only address the Netherlands as my problem area. Ophthalmology practices beyond the Netherlands are likely to be similar, yet for feasibility sake I will confine myself thus.

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.

Design a solution that will improve the wellbeing of Ophthalmologists by improving the physical ergonomics of their daily activities.

After conducting a research with the stakeholders and relevant literature I will design a physical design solution / product to address this problem.

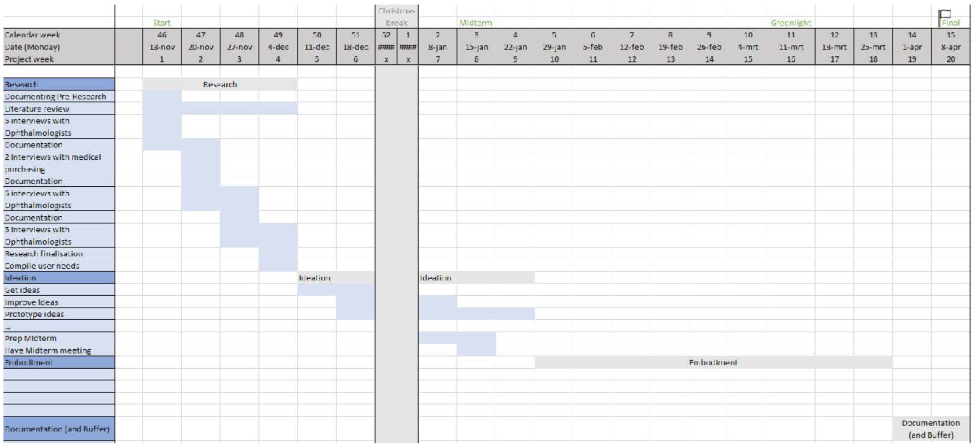
This choice for a physical design solution is both due to NOG's pronounced preference for a concrete, usable end result to this project, and my own expertise and preference for physical product design.

As mentioned, in improving the ergonomics I will (initially) only focus on the Split lamp. This is the device that Opthalmologists, by far, interact with the most during consultations. Most Opthalmologists in the Netherlands appear to use split lamps from producer Haag Streit. The product I am designing then, could be an improvement on the split lamp or an addition to the existing product.

Personal Project Brief - IDE Master Graduation

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 17 - 11 - 2023 12 - 4 - 2024 end date



This is a provisional planning that illustrates the activities during the project. It will evolve as the project progresses. The green highlighted Midterm, Greenlight and Final headers indicate when interim presentations will take place.

Personal Project Brief - IDE Master Graduation

MOTIVATION AND PERSONAL AMBITIONS
Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

What motivated me to set up this project was the physical nature of it. The problem is concrete, tangible and the problem owners are motivated to solve the problem.

Furthermore, my interest and expertise in the designing of physical mechanisms was awakened when I discovered this problem space. I am excited to put these skills to work to devise a solution.

My internship at WAACS before the summer further confirmed my love for design drawing. I therefore once again want to use this project to further improve this skill.

Lastly, I want to get better at price indications when it comes to product concepts. Getting a better grasp on the impact certain design decisions have on the final consumer price will be a useful skill.

FINAL COMMENTS
In case your project brief needs final comments, please add any information you think is relevant.

Appendix 3 : Research Ethics Checklist

Delft University of Technology
HUMAN RESEARCH ETHICS
CHECKLIST FOR HUMAN RESEARCH
(Version January 2022)

IMPORTANT NOTES ON PREPARING THIS CHECKLIST

1. An HREC application should be submitted for every research study that involves human participants (as Research Subjects) carried out by TU Delft researchers
2. Your HREC application should be submitted and approved **before** potential participants are approached to take part in your study
3. All submissions from Master's Students for their research thesis need approval from the relevant Responsible Researcher
4. The Responsible Researcher must indicate their approval of the completeness and quality of the submission by signing and dating this form OR by providing approval to the corresponding researcher via email (included as a PDF with the full HREC submission)
5. There are various aspects of human research compliance which fall outside of the remit of the HREC, but which must be in place to obtain HREC approval. These often require input from internal or external experts such as Faculty Data Stewards, Faculty HSE advisors, the TU Delft Privacy Team or external Medical research partners.
6. You can find detailed guidance on completing your HREC application here
7. Please note that incomplete submissions (whether in terms of documentation or the information provided therein) will be returned for completion **prior to any assessment**
8. If you have any feedback on any aspect of the HREC approval tools and/or process you can leave your comments here

I. Applicant Information

PROJECT TITLE:	**Improving the Ergonomic working conditions of Ophthalmologists**
Research period: *Over what period of time will this specific part of the research take place*	**17/11/2023 - 12/04/2024**
Faculty:	**Industrial Design Engineering (IDE)**
Department:	**-**
Type of the research project: *(Bachelor's, Master's, DreamTeam, PhD, PostDoc, Senior Researcher, Organisational etc.)*	**Master's**
Funder of research: *(EU, NWO, TUD, other – in which case please elaborate)*	**NOG (Nederlands Oogheelkundig Gezelschap)**
Name of Corresponding Researcher: *(If different from the Responsible Researcher)*	**Yan Michon**
E-mail Corresponding Researcher: *(If different from the Responsible Researcher)*	
Position of Corresponding Researcher: *(Masters, DreamTeam, PhD, PostDoc, Assistant/ Associate/ Full Professor)*	**Masters**
Name of Responsible Researcher: ***Note:** all student work must have a named Responsible Researcher to approve, sign and submit this application*	**Gonny Hoekstra**
E-mail of Responsible Researcher: *Please ensure that an institutional email address (**no Gmail, Yahoo, etc.**) is used for all project documentation/ communications including Informed Consent materials*	
Position of Responsible Researcher : *(PhD, PostDoc, Associate/ Assistant/ Full Professor)*	**Teacher of practice**

II. Research Overview

NOTE:** You can find more guidance on completing this checklist **here

a) Please summarise your research very briefly (100-200 words)

What are you looking into, who is involved, how many participants there will be, how they will be recruited and what are they expected to do?

Add your text here – (please avoid jargon and abbrevations)

Ophthalmologists are physicians with the subspecialty training in medical and surgical eye care. They often cope with long-term musculoskeletal injuries in the wrists and hands as well as the neck and shoulders. The goal for this project is to reduce these types of injuries.
The goal for this research, is to gather the necessary information to know enough about the context to be able to start ideation for a product design proposal. The research participants are ophthalmologists actively employed in any of three types of medical institutions: Hospitals, independent treatment centres (ZBC, Dutch abbr.) and/or university medical centres. The target number of participants is 15. They will be recruited from the NOG's established contacts. In the research, participants will be asked to work in their usual workplace for 1 to 2 hours. During and/or after this observational period, the researcher asks several questions relating to the work, the participant's health in relation to the work and the larger context.

b) **If your application is an additional project** related to an existing approved HREC submission, please provide a brief explanation including the existing relevant HREC submission number/s.

Add your text here – (please avoid jargon and abbrevations)

c) **If your application is a simple extension of, or amendment to,** an existing approved HREC submission, you can simply submit an HREC Amendment Form as a submission through LabServant.

III. Risk Assessment and Mitigation Plan

NOTE: You can find more guidance on completing this checklist here

Please complete the following table in full for all points to which your answer is "yes". Bear in mind that the vast majority of projects involving human participants as Research Subjects also involve the collection of **Personally Identifiable Information (PII)** and/or **Personally Identifiable Research Data (PIRD)** which may pose potential risks to participants as detailed in Section G: Data Processing and Privacy below.

To ensure alighment between your risk assessment, data management and what you agree with your Research Subjects you can use the last two columns in the table below to refer to specific points in your Data Management Plan (DMP) and Informed Consent Form (ICF) **– but this is not compulsory**.

It's worth noting that **you're much more likely to need to resubmit your application if you neglect to identify potential risks**, than if you identify a potential risk and demonstrate how you will mitigate it. If necessary, the HREC will always work with you and colleagues in the Privacy Team and Data Management Services to see how, if at all possible, your research can be conducted.

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	Yes	No	RISK ASSESSMENT – what risks could arise? *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	MITIGATION PLAN – what mitigating steps will you take? *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	DMP	ICF
A: Partners and collaboration						
1. Will the research be carried out in collaboration with additional organisational partners such as: • One or more collaborating research and/or commercial organisations • Either a research, or a work experience internship provider[1] *[1] If yes, please include the graduation agreement in this application*	X		**The organisation (NOG) is likely to learn more about the target demographic of ophthalmologists in the Netherlands.**	NOG is an independent interest group that was founded to serve the interests and protect the rights and long-term wellbeing of ophthalmologists in the Netherlands. Any information gathered and communicated will only be used to improve their situations, and even so, all personal identifiable data will be obscured.		
2. Is this research dependent on a Data Transfer or Processing Agreement with a collaborating partner or third party supplier? *If yes please provide a copy of the signed DTA/DPA*		X				
3. Has this research been approved by another (external) research ethics committee (e.g.: HREC and/or MREC/METC)? *If yes, please provide a copy of the approval (if possible) and summarise any key points in your Risk Management section below*		X				
B: Location						

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	Yes	No	RISK ASSESSMENT – what risks could arise? *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	MITIGATION PLAN – what mitigating steps will you take? *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	DMP	ICF
4. Will the research take place in a country or countries, other than the Netherlands, within the EU?		X				
5. Will the research take place in a country or countries outside the EU?		X				
6. Will the research take place in a place/region or of higher risk – including known dangerous locations (in any country) or locations with non-democratic regimes?		X				
C: Participants						
7. Will the study involve participants who **may** be vulnerable and possibly (legally) unable to give informed consent? (e.g., children below the legal age for giving consent, people with learning difficulties, people living in care or nursing homes,).		X				
8. Will the study involve participants who **may** be vulnerable under specific circumstances and in specific contexts, such as victims and witnesses of violence, including domestic violence; sex workers; members of minority groups, refugees, irregular migrants or dissidents?		X				
9. Are the participants, outside the context of the research, in a dependent or subordinate position to the investigator (such as own children, own students or employees of either TU Delft and/or a collaborating partner organisation)? *It is essential that you safeguard against possible adverse consequences of this situation (such as allowing a student's failure to participate to your satisfaction to affect your evaluation of their coursework).*		X				
10. Is there a high possibility of re-identification for your participants? (e.g., do they have a very specialist job of which there are only a small number in a given country, are they members of a small community, or employees from a partner company collaborating in the research? Or are they one of only a handful of (expert) participants in the study?		X				
D: Recruiting Participants						
11. Will your participants be recruited through your own, professional, channels such as conference attendance lists, or through specific network/s such as self-help groups		X				
12. Will the participants be recruited or accessed in the longer term by a (legal or customary) gatekeeper? (e.g., an adult professional working with children; a community leader or family member who has this customary role – within or outside the EU; the data producer of a long-term cohort study)		X				

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	Yes	No	RISK ASSESSMENT – what risks could arise? *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	MITIGATION PLAN – what mitigating steps will you take? *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	DMP	ICF
13. Will you be recruiting your participants through a crowd-sourcing service and/or involve a third party data-gathering service, such as a survey platform?		X				
14. Will you be offering any financial, or other, remuneration to participants, and might this induce or bias participation?		X				
E: Subject Matter *Research related to medical questions/health may require special attention. See also the website of the CCMO before contacting the HREC.*						
15. Will your research involve any of the following: • Medical research and/or clinical trials • Invasive sampling and/or medical imaging • Medical and *In Vitro Diagnostic Medical* Devices Research		X				
16. Will drugs, placebos, or other substances (e.g., drinks, foods, food or drink constituents, dietary supplements) be administered to the study participants? *If yes see here to determine whether medical ethical approval is required*		X				
17. Will blood or tissue samples be obtained from participants? *If yes see here to determine whether medical ethical approval is required*		X				
18. Does the study risk causing psychological stress or anxiety beyond that normally encountered by the participants in their life outside research?		X				
19. Will the study involve discussion of personal sensitive data which could put participants at increased legal, financial, reputational, security or other risk? (e.g., financial data, location data, data relating to children or other vulnerable groups) *Definitions of sensitive personal data, and special cases are provided on the TUD Privacy Team website.*		X				
20. Will the study involve disclosing commercially or professionally sensitive, or confidential information? (e.g., relating to decision-making processes or business strategies which might, for example, be of interest to competitors)		X				
21. Has your study been identified by the TU Delft Privacy Team as requiring a Data Processing Impact Assessment (DPIA)? *If yes please attach the advice/ approval from the Privacy Team to this application*		X				
22. Does your research investigate causes or areas of conflict? *If yes please confirm that your fieldwork has been discussed with the appropriate safety/security advisors and approved by your Department/Faculty.*		X				

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	Yes	No	RISK ASSESSMENT – what risks could arise? *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	MITIGATION PLAN – what mitigating steps will you take? *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	DMP	ICF
23. Does your research involve observing illegal activities or data processed or provided by authorities responsible for preventing, investigating, detecting or prosecuting criminal offences *If so please confirm that your work has been discussed with the appropriate legal advisors and approved by your Department/Faculty.*		X				
F: Research Methods						
24. Will it be necessary for participants to take part in the study without their knowledge and consent at the time? (e.g., covert observation of people in non-public places).		X				
25. Will the study involve actively deceiving the participants? (For example, will participants be deliberately falsely informed, will information be withheld from them or will they be misled in such a way that they are likely to object or show unease when debriefed about the study).		X				
26. Is pain or more than mild discomfort likely to result from the study? And/or could your research activity cause an accident involving (non-) participants?		X				
27. Will the experiment involve the use of devices that are not 'CE' certified? *Only, if 'yes': continue with the following questions:*		X				
• Was the device built in-house?						
• Was it inspected by a safety expert at TU Delft? *If yes, please provide a signed device report*						
• If it was not built in-house and not CE-certified, was it inspected by some other, qualified authority in safety and approved? *If yes, please provide records of the inspection*						
28. Will your research involve face-to-face encounters with your participants and if so how will you assess and address Covid considerations?	X		**During observations, the researcher will be in the same room, i.e. working context of the doctor.**	As Covid19 fades away, most medical institutions are dropping more rigid Covid guidelines. Interactions such as handshakes are conducted following personal and institutional guidelines/preferences.		
29. Will your research involve **either:** a) "big data", combined datasets, new data-gathering or new data-merging techniques which might lead to re-identification of your participants **and/or** b) artificial intelligence or algorithm training where, for example biased datasets could lead to biased outcomes?		X				
G: Data Processing and Privacy						
30. Will the research involve collecting, processing and/or storing any directly identifiable PII (Personally Identifiable Information) including name or email	X		**For communication and research purposes, personal information is gathered.**	Any such information is safely stored by the researcher only, and never shared further.		

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	Yes	No	RISK ASSESSMENT – what risks could arise? *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	MITIGATION PLAN – what mitigating steps will you take? *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	DMP	ICF
address that will be used for administrative purposes only? (eg: obtaining Informed Consent or disbursing remuneration)						
31. Will the research involve collecting, processing and/or storing any directly or indirectly identifiable PIRD (Personally Identifiable Research Data) including videos, pictures, IP address, gender, age etc and **what other Personal Research Data** (including personal or professional views) will you be collecting?	X		**Information gathered includes: pictures, in training or not, gender, years active in profession, type of medical institution employed in.** **During the observation, the doctor interacts with and diagnoses patients. Medical information is hence disclosed to the researcher.**	All participants fill out an informed consent form prior to participation. This includes consent to recording/taking of personally identifiable footage (notes, pictures and/or video's) None of this medical information is recorded as the focus of the research is on the doctor, not the patient. Any footage that is, with consent, taken of the doctor, will never depict the patient present.		
32. Will this research involve collecting data from the internet, social media and/or publicly available datasets which have been originally contributed by human participants	X		**Research data might be gathered for literature studies and other research purposes. Data produced by humans can be biased.**	Such data will only be gathered in the form of published papers or from other reputable sources such as ScienceDirect, Springer, Elsevier, etc. or ophthalmology and/or ergonomics related sources of similar report.		
33. Will your research findings be published in one or more forms in the public domain, as e.g., Masters thesis, journal publication, conference presentation or wider public dissemination?	X		**Findings can and will be published as part of Master's thesis, internal and/or public TU Delft communication and personal portfolio documents. This includes findings based on participant feedback.**	Any sensitive and/or personally identifiable participant data will be obscured.		
34. Will your research data be archived for re-use and/or teaching in an open, private or semi-open archive?		X				

H: More on Informed Consent and Data Management

NOTE: You can find guidance and templates for preparing your Informed Consent materials) ***here***

Your research involves human participants as Research Subjects if you are recruiting them or actively involving or influencing, manipulating or directing them in any way in your research activities. This means you must seek informed consent and agree/ implement appropriate safeguards regardless of whether you are collecting any PIRD.

Where you are also collecting PIRD, and using Informed Consent as the legal basis for your research, you need to also make sure that your IC materials are clear on any related risks and the mitigating measures you will take – including through responsible data management.

Got a comment on this checklist or the HREC process? You can leave your comments here

IV. Signature/s

Please note that by signing this checklist list as the sole, or Responsible, researcher you are providing approval of the completeness and quality of the submission, as well as confirming alignment between GDPR, Data Management and Informed Consent requirements.

Name of Corresponding Researcher (if different from the Responsible Researcher) (print)

Signature of Corresponding Researcher:

Date: 9 January 2023

Name of Responsible Researcher (print)

Signature (or upload consent by mail) Responsible Researcher:

Date:

V. Completing your HREC application

Please use the following list to check that you have provided all relevant documentation

Required:

- **Always:** This completed HREC checklist
- **Always:** A data management plan (reviewed, where necessary, by a data-steward)
- **Usually:** A complete Informed Consent form (including Participant Information) and/or Opening Statement (for online consent)

Onderzoek over Ergonomische werkomstandigheden van Oogartsen

Dit onderzoek wordt uitgevoerd als onderdeel van de MSc opleiding Industrieel Ontwerpen aan de TU Delft.

Student: Yan Michon

Contact informatie: Yan Michon,

Toestemmingsverklaring participant

Ik neem vrijwillig deel aan dit onderzoek.

Ik erken dat ik vooraf voldoende informatie en uitleg heb gekregen over dit onderzoek en al mijn vragen zijn naar voldoening beantwoord. Ik heb de tijd gekregen die ik nodig had om in te stemmen met de deelname. Op elk moment kan ik vragen stellen met betrekking tot het onderzoek.

Mij is bekend dat dit onderzoek bestaat uit:

1. Observatie door de student van het werken in de poli
2. Een interview met vooraf bepaalde en/of spontane vragen.
3. Aantekeningen die worden gemaakt naar aanleiding van boven genoemde
4. Het maken van foto's van werkzaamheden in de poli
5. Eventuele vragen die via de mail gestuurd worden

Ik ben mij ervan bewust dat tijdens het onderzoek gegevens worden verzameld in de vorm van bijvoorbeeld aantekeningen, foto's en/of video's. Ik geef toestemming voor het verzamelen van deze gegevens en het maken van geluidsopnames, foto's en video opnames tijdens het onderzoek. Gegevens zullen geanonimiseerd worden verwerkt en geanalyseerd (zonder naam of andere identificeerbare informatie). Deze gegevens zijn alleen voor het onderzoeksteam en hun TU Delft begeleiders beschikbaar.

De foto's en/of video's zullen worden gebruikt ter ondersteuning van het analyseren van verzamelde gegevens. Video opnames en foto's kunnen tevens worden gebruikt ter illustratie van onderzoeksbevindingen in publicaties en presentaties over het project.

Ik geef toestemming voor het gebruik van foto's en video opnames van mijn deelname:
(selecteer wat van toepassing is)

- ☐ waarin ik herkenbaar ben voor publicaties en presentaties over het project.
- ☐ waarin ik niet herkenbaar ben voor publicaties en presentaties over het project.
- ☐ enkel voor data analyse doeleinden en niet voor publicaties en presentaties over het project.

Ik geef toestemming om gegevens nog maximaal 5 jaar na afloop van dit onderzoek te bewaren en te gebruiken voor onderwijs- en onderzoeksdoeleinden.

Ik erken dat er geen financiële compensatie gegeven wordt voor deelname aan het onderzoek.

Met mijn handtekening bevestig ik dat ik de informatie over het onderzoek heb gelezen en dat ik de aard van mijn deelname heb begrepen. Ik begrijp dat ik mijn deelname aan het onderzoek op elk moment kan intrekken of kan stoppen. Ik begrijp dat ik niet verplicht ben om vragen te beantwoorden die ik niet wil beantwoorden en dat ik dit kan aangeven bij het onderzoeksteam.

De onderzoekers nemen de COVID-19 richtlijnen in acht. Als deelnemer aan dit onderzoek zal ik de COVID-19 maatregelen respecteren en de aanwijzingen hierover van de onderzoekers opvolgen.

Een kopie van deze toestemmingsverklaring zal aan mij worden gegeven.

________________________	________________________
Achternaam	Voornaam
___ / ___ / 2021	________________________
Datum (dd/mm/jjjj)	Handtekening

Please also attach any of the following, if relevant to your research:

Document or approval	Contact/s
Full Research Ethics Application	After the assessment of your initial application **HREC will let you know if and when you need to submit additional information**
Signed, valid Device Report	Your Faculty HSE advisor
Ethics approval from an external Medical Committee	TU Delft Policy Advisor, Medical (Devices) Research
Ethics approval from an external Research Ethics Committee	Please append, if possible, with your submission
Approved Data Transfer or Data Processing Agreement	Your Faculty Data Steward and/or TU Delft Privacy Team
Approved Graduation Agreement	Your Master's thesis supervisor
Data Processing Impact Assessment (DPIA)	TU Delft Privacy Team
Other specific requirement	Please reference/explain in your checklist and append with your submission

Appendix 4 : Informed Consent Form

Onderzoek over Ergonomische werkomstandigheden van Oogartsen

Dit onderzoek wordt uitgevoerd als onderdeel van de MSc opleiding Industrieel Ontwerpen aan de TU Delft.

Student: Yan Michon

Contact informatie: Yan Michon,…

Toestemmingsverklaring participant

Ik neem vrijwillig deel aan dit onderzoek.

Ik erken dat ik vooraf voldoende informatie en uitleg heb gekregen over dit onderzoek en al mijn vragen zijn naar voldoening beantwoord. Ik heb de tijd gekregen die ik nodig had om in te stemmen met de deelname. Op elk moment kan ik vragen stellen met betrekking tot het onderzoek.

Mij is bekend dat dit onderzoek bestaat uit:

1. Observatie door de student van het werken in de poli
2. Een interview met vooraf bepaalde en/of spontane vragen.
3. Aantekeningen die worden gemaakt naar aanleiding van boven genoemde
4. Het maken van foto's van werkzaamheden in de poli
5. Eventuele vragen die via de mail gestuurd worden

Ik ben mij ervan bewust dat tijdens het onderzoek gegevens worden verzameld in de vorm van bijvoorbeeld aantekeningen, foto's en/of video's. Ik geef toestemming voor het verzamelen van deze gegevens en het maken van geluidsopnames, foto's en video opnames tijdens het onderzoek. Gegevens zullen geanonimiseerd worden verwerkt en geanalyseerd (zonder naam of andere identificeerbare informatie). Deze gegevens zijn alleen voor het onderzoeksteam en hun TU Delft begeleiders beschikbaar.

De foto's en/of video's zullen worden gebruikt ter ondersteuning van het analyseren van verzamelde gegevens. Video opnames en foto's kunnen tevens worden gebruikt ter illustratie van onderzoeksbevindingen in publicaties en presentaties over het project.

Ik geef toestemming voor het gebruik van foto's en video opnames van mijn deelname:
(selecteer wat van toepassing is)

- ☐ waarin ik herkenbaar ben voor publicaties en presentaties over het project.
- ☐ waarin ik niet herkenbaar ben voor publicaties en presentaties over het project.
- ☐ enkel voor data analyse doeleinden en niet voor publicaties en presentaties over het project.

Ik geef toestemming om gegevens nog maximaal 5 jaar na afloop van dit onderzoek te bewaren en te gebruiken voor onderwijs- en onderzoeksdoeleinden.

Ik erken dat er geen financiële compensatie gegeven wordt voor deelname aan het onderzoek.

Met mijn handtekening bevestig ik dat ik de informatie over het onderzoek heb gelezen en dat ik de aard van mijn deelname heb begrepen. Ik begrijp dat ik mijn deelname aan het onderzoek op elk moment kan intrekken of kan stoppen. Ik begrijp dat ik niet verplicht ben om vragen te beantwoorden die ik niet wil beantwoorden en dat ik dit kan aangeven bij het onderzoeksteam.

De onderzoekers nemen de COVID-19 richtlijnen in acht. Als deelnemer aan dit onderzoek zal ik de COVID-19 maatregelen respecteren en de aanwijzingen hierover van de onderzoekers opvolgen.

Een kopie van deze toestemmingsverklaring zal aan mij worden gegeven.

________________________	________________________
Achternaam	Voornaam
___ / ___ / 2023	________________________
Datum (dd/mm/jjjj)	Handtekening

Appendix 5 : Pre-Research

Leading up to my kick-off meeting: the official start of the thesis project, I conducted preliminary research, which for this reason I refer to as pre-research. In this appendix I will provide transcripts of the two conversations I had in this period, that formed my expectations for the main research phase.

Appendix 5.1: First Ophthalmologist visit

The first in person research I did was a visit to an ophthalmic outpatient clinic in Rotterdam, where I had a conversation with one of their ophthalmologists. This ophthalmologist is also a member of the NOG professional interests committee (Beroepsbelangen Commissie, BBC), specialising in workplace ergonomics. Lines in blue italics below are transcripts of their comments.

--Transcript—

Firstly it is important to understand the difference between the different eye-related medical professions. So an ophthalmologist has the highest level of education and generally a leading role in the clinic. Their work is characterized by short patient appointments and a rather high workload. These many patients in a day put the ophthalmologist under time pressure and increase risk of MSD's. this is exacerbated by repetitive small hand and finger movements to use the equipment.

And optician has longer appointments characterised by less monotony meaning fewer repetitive movements. As their field is not medical, but instead planned, they see fewer people per day and are thus under less pressure and under lower risk of RSI/MSD's.

Optometrist have followed HBO level medical education and perform low complexity ophthalmological examination. They can do varied things within hospitals.

Technical research assistants have followed MBO level education and do specific technical supportive work for ophthalmologists.

-- --

During the visit I was also able to observe several patient examinations. The first thing I observed is that the doctor has to sit turned sideways to view both screen and patient.

Furthermore, adjustments to the slit lamp involve a lot of turning of the small wheels and levers.

--Transcript—

I started suffering from pain in my wrists and fingers several years ago. I ascribe these to the many adjustments I have to do to the slit lamp in a patient visit. If these could be improved, that would solve a lot of problems for me and other doctors. There aren't really any guidelines on ergonomic working. It might be good to teach starting ophthalmologists more about this during training. When my problems started I contacted maintenance, they recommended working with a lighter lubricant in the slit lamp I use to reduce the force required to adjust it. I have been working thus ever since, it helps a bit, but it also has to be replenished more often.

-- --

An early idea I had to reduce the necessary movements in adjustment, was a binocular-inspired division, where big changes are made with a separate wheel, and finetuning is done with another.

Another observation was around the chair the doctor uses. This is already a very ergonomic chair with a saddle like design.

One ergonomic intervention that is already in place is an elbow support that supports the doctor's arm during retinal checkups, so that it is no longer 'hanging in the air'.

Appendix 5.2: Medical instrument technicians visit

The second visit was to the medical instrument technicians at Oogziekenhuis Rotterdam. Because this hospital specialises in eye care, its medical instrument technicians provide ophthalmic equipment maintenance for not only this hospital, specialising in yearly slit lamp maintenance, but for several medical institutions in the Netherlands.

I interviewed one of their technicians, whom as we talked disassembled a slit lamp, an ophthalmologist's most used piece of equipment, to show its parts, mechanism and functionalities. Lines in blue italics below are transcripts of their comments.

Question 1: What brands are there in slit lamps and how do they differ?

Haag Streit is the market leader in the Netherlands, their lamps are expensive but the most popular.

CSO is a another brand that you see more with opticians. They're better for lasering due to different 'depth of field' and a bit cheaper.

Topcon and Huvitz also produce slit lamps.

It depends on many things what brand is used. With lens makers, for instance you often see cheaper models because they have a different business model.

These are producers, but hospitals buy such equipment from suppliers. There are 4 main suppliers in the Netherlands. How it goes is, the equipment is made by a producer, it is supplied to medical institutions by a supplier, and another party does maintenance on them.

Question 2: What are the parts of a slit lamp?

This question was mainly answered by the slit lamp disassembly. The main parts are the base, including the rails, the adjustment lever, and support springs. On top of this sits the arm that supports the eyepiece. Its height and position is determined entirely by the base's position. On top sits the lamp module (Figure 8-1, below), which can be pivoted from side to side to aim the light beam at the patient's eye in different angles. For more information on the slit lamp's parts and functionalities, see 8Appendix 6 : Ophthalmological Clinic Analysis: Slit Lamp.

Figure 8-1: Slit Lamp eyepiece (back) and Lamp module (front)

Question 3: What is the average purchase price of a slit lamp?

It's around 20,000 to 30,000 if you go for the best option. There are other options around 6000 to 8000.

Question 4: What are the parts in a slit lamp that break the most?

In any case, the lubricant gets old and needs to be replaced once a year

The caps on the bottom rails break quickly because they are plastic and are firmly attached, but they are not replaced immediately because otherwise they would have to 'constantly replace them'.

Question 5: What kind of certifications/laws are attached to such a device?

It can take a long time between design and market acceptance. This is really a very conservative market.

The optimal way of working with the equipment right now, for the ophthalmologist, in terms of ergonomics is: adjust your office chair first, then the slit lamp, and then the patient chair. This way you adjust everything to yourself as much as possible. But what happens more often in reality, is they adjust everything to the patient. This is a strong habit.

Speaking about habits, the oldest model of these slit lamp is from 1974. The ones you see these days have really changed very little compared to that one. You do see some developments in terms of ergonomics in other devices, but less so in slit lamps.

Question 6: Why is there no solution yet that truly improves ergonomics?

I think it's conservatism. The big producers will sell their products anyway, so they don't have to change. Those big producers are not located in the Netherlands either, so maybe they don't hear of the problems, but I can't imagine these problems not to exist internationally.

Lighter lubricant does make it easier to move the device, but it also lasts less long.

The 3 support springs in the back can be separately activated, so you can choose how much support you get when moving upwards. It is either 'on' or 'off', per spring, so there is no spectrum.

Slit lamps are taken apart once a year for maintenance and lubrication, Sometimes it is less or more, depending on how well the maintenance was done last time, but also how much they are used.

Figure 8-2: Slit lamp support springs

Figure 8-3: Slit lamp bottom section

Ball bearings being cast in plastic is a change that has been made in recent years. And LED lamps have come in, which also appear to be better. Here and there, parts start being made more of plastic. The rails caps are made of ABS, and break a lot. They are not essential, but when driving towards you it can otherwise ride off the rails.

Many parts can certainly be tightened or loosened, which decides how easily they move, but if you loosen too much, the slit lamp will sink down, but too tight and adjustment will be difficult.

Doctors are part of the conservatism. I find that they find new things/changes difficult.

Question 7: What other peripheral equipment is used by ophthalmologists?

Eye pressure meter, Autorefractor, OCT (Optical Coherence Tomography)

Question 8: What are the main adjustments done to a slit lamp by the user

Eyepiece adjustment, Adjustment of the lamp, Table adjustments, the chin rest.

The only electronics in the slit lamp are the lamp, and the camera, if there is one on it. A camera isn't always installed on it. You could possibly replace the springs in the base with an electro motor, but that would make it more complex.

This hospital keeps all equipment the same in every room so that every doctor can work anywhere, but that isn't always the case. We have 50 slit lamps. Some other hospitals that have a smaller ophthalmic clinic often have much fewer. This is also why many hospitals don't have their own technicians, and why we do maintenance for other hospitals.

-- --

These two visits were the basis for my understanding of the ophthalmic context in the Netherlands.

Appendix 6 : Ophthalmological Clinic Analysis: Slit Lamp, Table & Patient chair

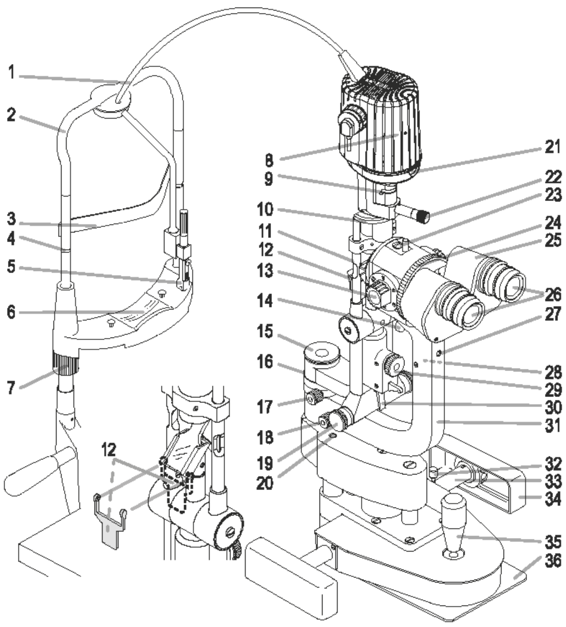
In this appendix, I will provide background information on the equipment used in an ophthalmic room. First I will give a synopsized explanation of the functionalities and construction of a slit lamp, the most common piece of ophthalmic equipment; after this I will elaborate on the table unit that this slit lamp stands on; thirdly I will describe the patient chair and lastly I will give a brief description of other table top equipment beside the slit lamp that an ophthalmologist might use.

Appendix 6.1: Slit Lamp

A large part of an ophthalmologist's daily activities is centred around the slit lamp. The slit lamp is the main piece of examination equipment used by ophthalmologists. It allows the doctor to look into/onto the patient's eye with an array of magnifications. As explained by Kaur (2023): '*A slit lamp is the most common ophthalmic equipment used by ophthalmologists in daily clinical practice. It is an essential instrument in the ophthalmologist armamentarium. Slit lamp not only provides a magnified view of intraocular structures (anterior and posterior segment) but also help in qualitative and quantitative analysis of various parameters such as corneal endothelial cell count, corneal thickness, anterior chamber cells, and flare assessment, depth of anterior chamber, pupil size, grading of cataract, slit lamp photography, etc.*'

Figure 8-4: Slit lamp (HaagStreit BQ900)

The figure below is a schematic description of the parts of one of the most commonly used slit lamp models in the Netherlands, used by 14 out 14 visited ophthalmologists. Slit lamp parts are referred to in the text below by their number in the diagram.



3 Introduction

The slit lamp consists of an illumination and a binocular microscope. The instrument base can be used to move the entire device in front of the eyes. The illumination offers a large number of setting options to make the practically invisible areas in the eye visible. There is also a range of accessories available for the slit lamp to allow special diagnosis possibilities in addition to the general examinations.

3.1 Overview

1. Lamp cable
2. Headrest
3. Forehead band
4. Height mark on headrest (patient eye)
5. Adjustable fixation lamp
6. Chin rest
7. Height adjustment of chin rest
8. LED illumination LI 900, see separate manual
9. Lever for filters
10. Scale for angled position of the slit image (5° increments)
11. Illumination mirror
12. Diffusor
13. Magnification changer
14. Mounting screw for the stereo microscope
15. Protective cover
16. Illumination unit/microscope angle scale
17. Illumination arm locking screw
18. Microscope arm locking screw
19. Slit width controls
20. Weight compensation screws
21. Slit length/diaphragm scale
22. Setting screw for adjusting the slit length, blue filter and fixation star, handle for turning the slit
23. Cover screw for accessories pin
24. Quick-release fastener for accessories
25. Stereo microscope with eyepieces
26. Eyepieces
27. Thread for breath shield
28. Thread for fixing (right-hand side) the tonometer AT 900 model BQ or AT 900 D model BQ
29. Centring screw
30. Inclination angle latch 0 – 20°
31. Bearer arm
32. Instrument base locking screw
33. Axle
34. Rail cover
35. Control lever
36. Slide plate

Figure 8-5: Parts overview of a commonly used slit lamp (Haag Streit, n.d.)

Below are the most important parts:

- During examination, the patient rests their head on the separate **chin rest** (6).
- The ophthalmologist looks through the **eyepiece** (26), the image in this can be set to a set of different magnifications.
- The ophthalmologist adjusts sideways, frontal, and height position of the slit lamp with the **control lever** (35), by swaying it sideways, frontal, and rotating it respectively.
- The patient's eye is illuminated for optimal examination with the **LED module** (8) at the top of the device. The light beam shines straight down from this module, and is horizontally reflected into the eye with a small **mirror** (11). The light itself can be adjusted by the **sliders** (9&22).

Appendix 6.2: Table unit

The slit lamp itself, is bolted onto the table unit. The purpose of this table, opposed to any regular table, is that it **moves in front of the patient** when in use, and moves away after the examination, allowing the patient to get up again. The range over which a slit lamp can accurately magnify the eye, is very short. For this reason, the device, and thus the table needs to be very close to the patient. With a stationary patient chair, a regular stationary table would not allow the patient to get in and out of the chair. This is why the moving functionality is required. The table is controlled with a hand panel, generally affixed to the desk, or under the unit table top.

Three movement types exist within these units. The most common is a linear translation. 12 out of 15 ophthalmic clinics visited during the research had a table unit like this. From the interview with an industry representative (Appendix 8Appendix 22 :), I learned that this is because these linear tables are currently the only table units that provide full electromechanical movement, at the push of a button. Other table types are partially electromechanically supported, or not at all. Full electromechanical movement is preferred as this takes away significant physical stress from the ophthalmologist using it.

Linear tables move in front of the patient in a straight line. The tabletop in Figure 8-6 for instance, slides out to the right, to bring the slit lamp in front of the patient in the black chair.

To give the ophthalmologist access to the secondary examination equipment (right in the figure), it can also slide out yet further, to bring the secondary device in front of the patient.

The advantage to this movement type is that it is simple, and only needs linear actuators to function. it does not however accommodate the examination of wheel chair users, which is a significant disadvantage, except if the patient chair is physically moved away, which in practice hardly happens. Wheelchair patients thus either have to get out of their wheelchair with help from companions or the doctor, or be examined with the indirect ophthalmoscope, which is highly strenuous for the doctor (Fethke et al., 2015).

Figure 8-6: Ophthalmic table unit with linear translation (Medical Workshop, n.d.-a)

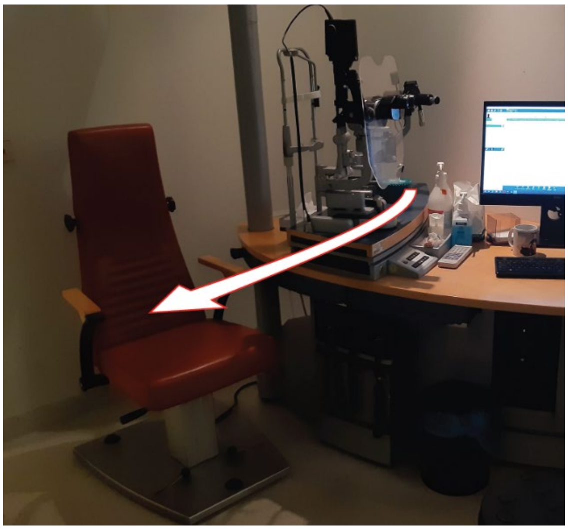


Figure 8-7: Ophthalmic table unit with Circular translation

The second movement type is **circular**.

The table on this type of unit moves in front of the patient in a circular line. The tabletop in Figure 8-7 for instance, will slide out to the left, to bring the slit lamp in front of the patient in the red chair.

This type is similar to the linear path, in that it also puts the tabletop on a track. The only difference is that this track is circular, instead of linear

To give the ophthalmologist access to the secondary examination equipment, it can also ride out further, to bring the secondary device on the far side of the table in front of the patient.

The disadvantage to this movement type, when compared to the simple linear movement, is higher complexity from the circular rail, with little gain because of it, perhaps except for the fact that the circular table takes up slightly less space

Another movement type are **swivel tables**. The table on this type of unit moves in front of the patient on a rotational axis. The tabletop in Figure 8-8 for instance, turns around the indicated vertical axis, to bring the slit lamp in front of the patient in the black chair.

To access secondary examination equipment, the table can slide out further from the arm. Depending on the model this is manual, or electrical.

A big advantage to this movement type is that it can facilitate wheelchair users to be examined by the ophthalmologist using it.

A disadvantage however is that tables of this type still need to be moved partially or entirely manually by the user, as no models exist yet with full electromechanical movement support.

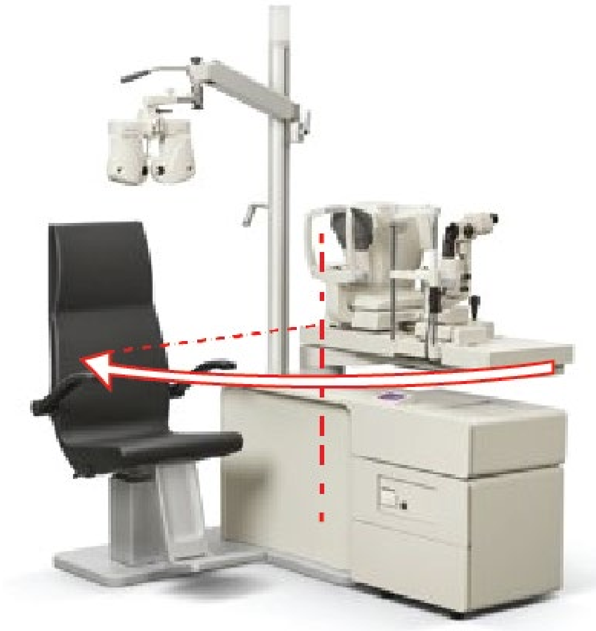


Figure 8-8: Ophthalmic table unit with Swivel movement

The last movement type is a table on a **two-point arm**.

The table on this type of unit moves in front of the patient on a rotational axis, similar to the swivel movement type. The difference between the two, is that this table unit type has two vertical axes instead of one. The tabletop in Figure 8-9 for instance, turns on the right vertical axis (in the right picture) at the end of the swivel arm, while the arm it sits on, itself rotates around the left vertical axis.

Figure 8-9: Ophthalmic table unit on two-point Arm

This model is perceived as old-fashioned as the whole movement is manual, without any motorised support for the heavy table. This makes it quite strenuous to use, and sub-optimal from an ergonomic perspective.

Appendix 6.3: Patient chair

The patient chair's purpose, apart from seating the patient, is to allow the ophthalmologist to raise and/or lower them, to bring their eyes level with the slit lamp lens. This is important as the slit lamp can only show the ophthalmologist what is directly in front of it.

This raising and lowering is either done with a foot pedal on the ground, or a hand panel affixed to the side of the table (See Figure 8-11). Generally both are present and active in the room, but the hand panel is the more preferred method of control. This is because all other interactions, such as with the table and room lights are already done with this panel. To therefore switch to the foot pedal only to raise the patient is uncommon.

Many patient chairs also allow the ophthalmologist to move the patient towards and away from them. This is important as the chair is generally stationary, and more corpulent patients might otherwise not fit behind the list lamp table.

Figure 8-10: The patient chair

Figure 8-11: Lesser used Foot pedal & more common Hand panel

The current dynamic range of the chair is 20cm, from 50cm seat off the ground, to 70cm off the ground. This movement takes almost 15 seconds, including a delay between the button press and the chair starting to move. See Clinic equipment measurements for further detailed measurements. Multiple ophthalmologists confirmed that this interaction is too slow. Furthermore, due to the brief time available per patient, this can result in no alteration being done at all.

Additionally, the short dynamic range of the chair makes it impossible to work in an ergonomic manner, when there is a substantial difference in height between the ophthalmologist and patient. This is often the case, as concluded during the research, for instance with the predominantly older patient demographic tending to be shorter. The conclusion is that the chair adjustability is needed for the ophthalmologist to work in an ergonomic fashion, and for the patient to be comfortable. However, the adjustment currently, is too slow and the range is too limited.

Appendix 7 : Research Script

This appendix includes the script I used during my visits to interview and observe ophthalmologists in their working context, during the research phase. The observational prompts and questions are based on the research questions. It is indicated under every prompt or question what sub-research question they are meant to answer, using the abbreviation Sub-Q: [number]. A reasoning per question is provided where the sub-question does not sufficiently explain its reason.

The lines that are underlined, were added to the script in Phase 2 of the research. These lines are based on the results from phase 1. It is indicated under these lines what phase 1 result they were based on using the abbreviation Ph1 Res [number].

Appendix 7.1: - Observation

First observe normal work activities without asking questions for at least 20 minutes.

1. What type of chair does the ophthalmologist have? [take photographs]
    - Sub-Q: 2)a *What physical workplace properties contribute to the complaints?*
    - Sub-Q: 3) *What measures are ophthalmologists currently taking to prevent or reduce physical complaints?*
    - Reason: An uncomfortable or non-adjustable chair could cause MSD's
2. Is the patient across from, or flanking the ophthalmologist? [make map]
    - Sub-Q: 2)b *What work-related behavioural patterns contribute to the complaints?*
    - Reason: The layout of the room could cause the ophthalmologist twist their spine regularly during patient visits to talk to patients/supervisors or otherwise. Regular spinal twisting is connected to developing MSD's (Algarni & Alkhaldi, 2021).
3. Is the equipment (slit lamp) adjusted for good posture of the doctor? (if not, ask about this later)
    - Sub-Q: 2)b *What work-related behavioural patterns contribute to the complaints?*
    - Reason: poor ergonomic adjustment of the equipment causes bad posture for the ophthalmologist using it, and heightens the chance of developing MSD's in the long run.
4. <u>Does the doctor adjust the slit lamp at the beginning of the day? Are further adjustments made throughout the day? For what reason?</u>
    - Ph1 Res 2: Some doctors make adjustments to the slit lamp and surrounding equipment during the day. This is either done to finetune for their own comfort or to accommodate the patient.
    - Reason: Best practice in terms of ergonomic posture is to properly adjust the equipment to yourself at the beginning of the day, and not adjusting it further throughout the day. Readjusting to accommodate patients worsens ophthalmologists' posture and heightens the risk of long term MSD's
5. What brand is the Slit Lamp?
    - Sub-Q: 2)a *What physical workplace properties contribute to the complaints?*
    - Reason: Observe whether there is a correlation between MSD prevalence and type of equipment used.
6. <u>How do they use the separate lens during retinal checkups? Where do they rest their arm and hand? Is the lens and/or the elbow rest passed from hand to hand?</u>
    - Ph1 Res 1: While performing retinal check-ups with a separate lens to the slit lamp, the hand and arm tend to be unsupported.
    - Reason: Inproper posture during retinal checkups could cause MSD's as considerable stress is put on the shoulder (Kent, 2011).

Appendix 7.2: Questions

Use the time between patients to ask questions. As the situations and time pressure per visit can differ slightly, the interviews are semi-structured. The goal is to gather qualitative data, rich in detail, to use in the design phase.

1. Do you have any lasting physical complaints?
    - Sub-Q: 1) *Which work-related physical complaints are most common among ophthalmologists?*
2. Are these related to your work, and/or do you see a connection between your work and these problems?
    - Reason: To confirm these complaints are work related.
3. When did these start? Early in your career or did it take a while?
    - Reason: To determine whether there is a shared timeline in the development of MSD's. It is valuable to determine whether there is a correlation between respondents characteristics or employers and the timeframe in which they develop MSD's.
4. What do you think is the cause of these problems? Or what is the biggest cause?
    - Sub-Q: 2) *What are the work-related risk factors that contribute to physical complaints?*
5. Do you have colleagues to whom this also applies?
    - Sub-Q: 1) *Which work-related physical complaints are most common among ophthalmologists?*
6. What do you do yourself to (try to) prevent, reduce and/or remedy these problems?
    - Sub-Q: 3) *What measures are ophthalmologists currently taking to prevent or reduce physical complaints?*
7. Is the equipment properly adjusted to you right now? When do you adjust the slit lamp and surrounding equipment? For what reason?
    - Do you adjust the slit lamp and other equipment more to your own comfort or the patient's?
    - Ph1 Res 2: Some doctors make adjustments to the slit lamp and surrounding equipment during the day. This is either done to finetune for their own comfort or to accommodate the patient.
8. Have you had contact with ergonomists, physiotherapists or other professionals from within the organization or on your own initiative who offer help with this?
    - Sub-Q: 3) *What measures are ophthalmologists currently taking to prevent or reduce physical complaints?*
    - Sub-Q: 4) *What is the stance of healthcare institutions as to the ergonomic working conditions of ophthalmologists, and what measures are being taken to protect them?*
9. Has there been a change in approach (of ergonomics and comfortable long term working conditions) over time in your organisation and the sector as a whole?
    - Sub-Q: 4) *What is the stance of healthcare institutions as to the ergonomic working conditions of ophthalmologists, and what measures are being taken to protect them?*
10. Are there any guidelines for the proper ergonomic use of the workspace in favour of longtime wellbeing?
    - Sub-Q: 4) *What is the stance of healthcare institutions as to the ergonomic working conditions of ophthalmologists, and what measures are being taken to protect them?*
11. Do you have insight into how this is different in adjacent professions? Such as Opticians, Optometrists, (any others?)
    - Reason: These other professions also provide eye-health-related services, if therefore the prevalence and/or nature of MSD's in these professions is different, it could point towards a conclusion on its causes.

12. What is the most annoying thing about the device? (is there anything that you want to change?)
    - Sub-Q: 2)a *What physical workplace properties contribute to the complaints?*
13. What is the most useful aspect of this device (Slit lamp and surrounding equipment) that should not change?
    - Reason: To become aware of needs and preferences of the users
14. What do you think about the direction of the eyepiece? What is your opinion on the corner piece to change the direction of the eyepiece?
    - Ph1 Res 3: A corner piece is often available to change the direction of the eyepiece from horizontal to slight upwards. Some ophthalmologists highly prefer these while others never (want to) use them.
15. Do you experience a high work pressure, and does this change depending on how much supporting staff (such as Technical ophthalmic assistants or optometrists) is present?
    - Ph1 Res 4

-- --

The results to these questions are included in appendices 10 and 11.

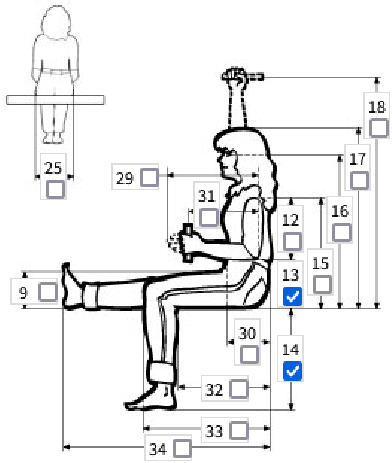
Appendix 8 : Clinic equipment measurements

To make valid claims about the value of the concept over the current alternative, I did measurements of the current equipment in ophthalmological clinics. These measurements are included in the table below.

Table 8-1: Measurements of the current ophthalmological equipment

Dynamic range eyepiece (measured from table surface)	Min: 42cm , Max: 45cm 7 seconds to move from one extreme to the other. Full movement requires 14 lever rotations
Dynamic range patient chair (measured from ground)	Min: 50cm, Max: 70cm, 13 seconds to move from one extreme to the other
Dynamic range slit lamp table (measured from ground to table surface)	Min : 78cm , Max: 98cm 11 seconds to move from one extreme to the other
Height difference between eyepiece and patient eye level	3,5 cm
Full slit lamp height (measured from table surface to top of slit lamp)	Min : 66cm, Max: 69cm
Dynamic range sideways motion slit lamp	10cm (5cm to both sides off centre)
Dynamic range frontal motion slit lamp	8cm
Dynamic range patient chin rest (measured from table surface to chin rest surface)	23cm tot 32cm
Height of elbow rest	4cm

The first conclusion that can be drawn on the ergonomic adjustment capabilities of the current examination unit, is on the dynamic height range of the slit lamp table (measured from ground to table surface). This range, as included in Table 8-1 above, is 780mm to 980mm. Below are measurements from the anatomical database DINED (DINED, n.d.).



The ideal posture, sitting behind a desk is with a straight back and arms resting on the table with horizontal forearms (Motmans, 2022c). This means the desk, and for the ophthalmological context the slit lamp table, should be at elbow height. The elbow height for Percentile 5, 50 and 95 (Figure 8-12), from the database, are shown in Table 8-2, as a combination of popliteal and elbow height from seat.

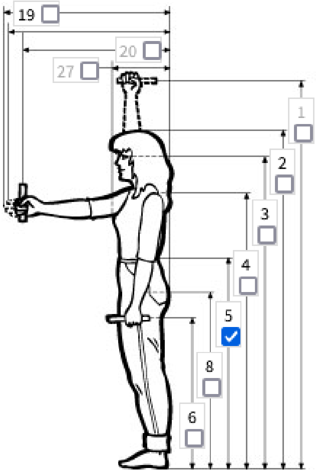
What this shows, is that while taller ophthalmologists can be accommodated by the equipment, shorter doctors (P5) cannot bring the table nearly low enough to be comfortable.

Figure 8-12: Seated measurements in DINED

Table 8-2: Seated height measurements

	Popliteal height Foot to Seat	Elbow Height Seat to Elbow	Ideal Table Height Foot to Elbow
P2	380	175	555
P5	395	188	583
P50	456	241	697
P95	517	294	811

P98	532	307	839



Similar measurements are available for standing figures, showing, in Figure 8-13 and Table 8-3, that for a standing ophthalmologist, the current unit cannot go high enough for any doctor. This was expected, but it shows what dynamic range is necessary to realise the concept.

This necessary dynamic range is min. 555mm – max. 1236mm.

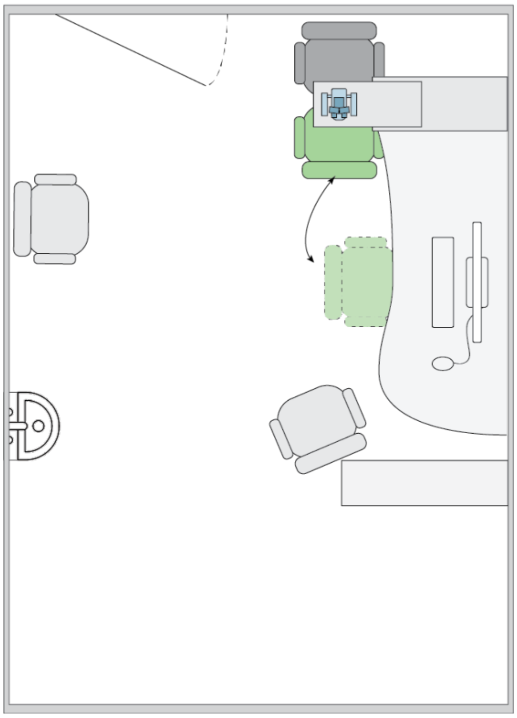
Figure 8-13: Standing measurements in DINED

Table 8-3: Standing height measurements

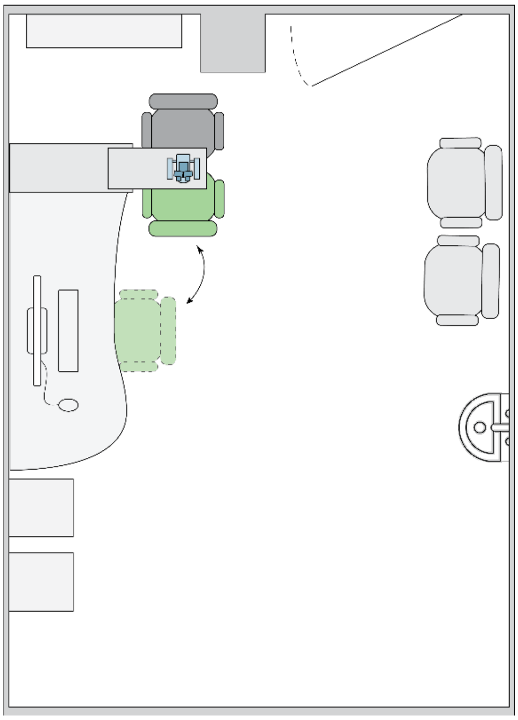
	Elbow Height Foot to Elbow	Ideal Table Height Foot to Elbow
P2	932	Idem
P5	962	Idem
P50	1084	Idem
P95	1206	Idem
P98	1236	Idem

Appendix 9 :Clinic maps

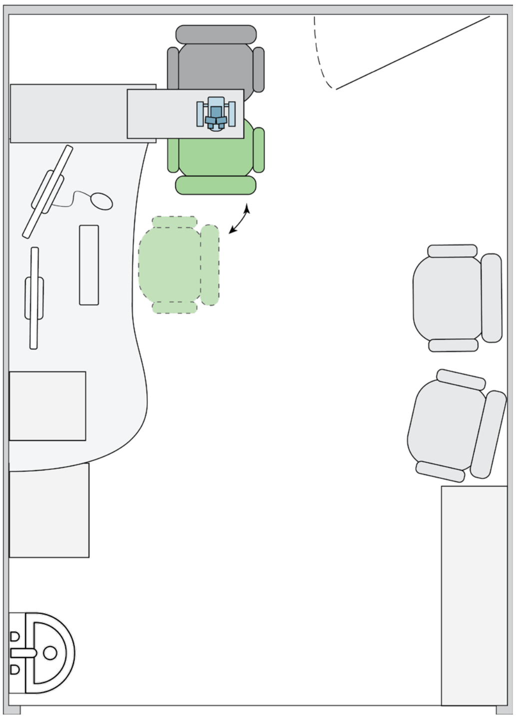
Below are schematic maps of ophthalmology practices visited in the research phase. The ophthalmologist is indicated by the green chair, as well as their movement between patient and desktop admin. Patient is indicated by the dark grey chair and companions by the light grey chairs.



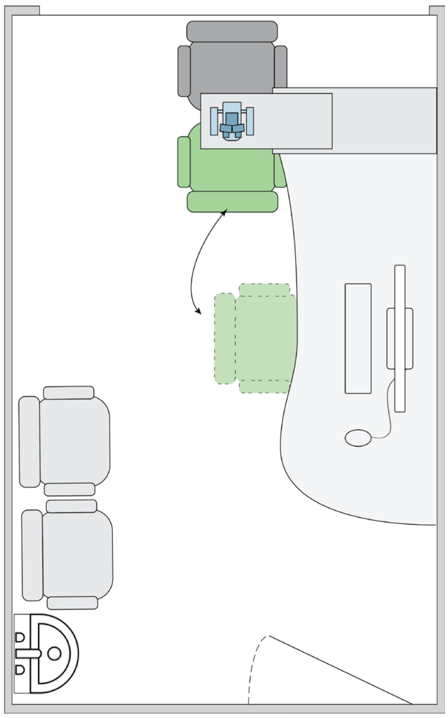
1: Patient flanking the Ophthalmologist on the left. Carers/companions behind.



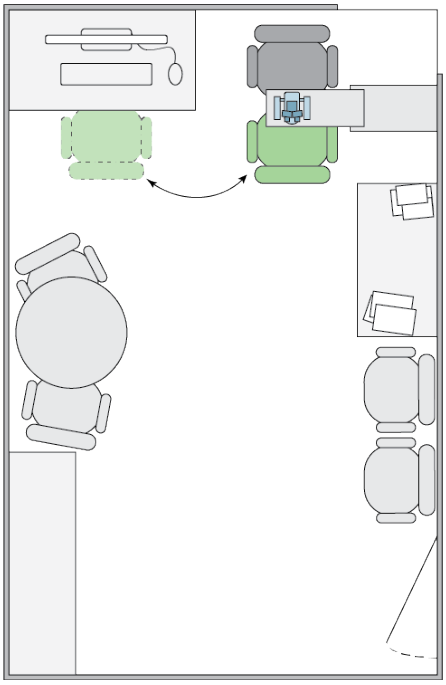
2: Patient flanking the Ophthalmologist, on the right. Carers/companions behind.



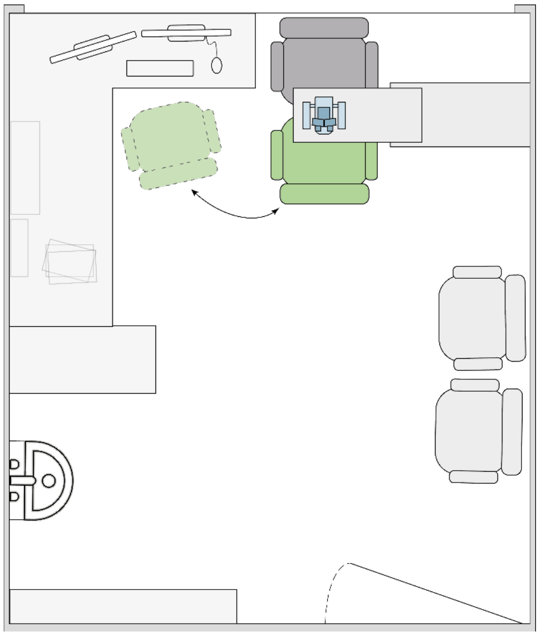
3: Patient flanking the Ophthalmologist on the right. Carers/companions behind.



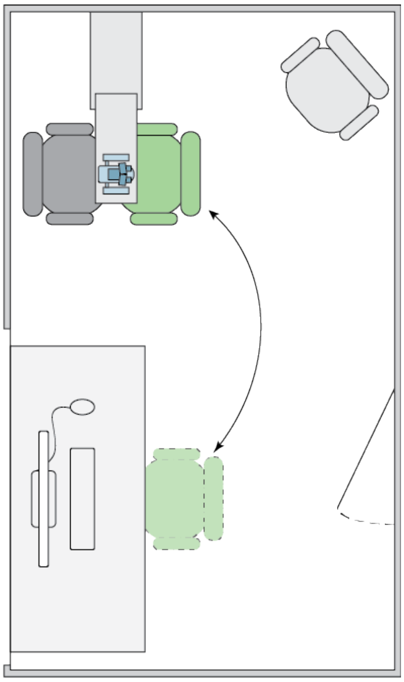
4: Patient flanking the Ophthalmologist, on the left. Carers/companions behind, right.



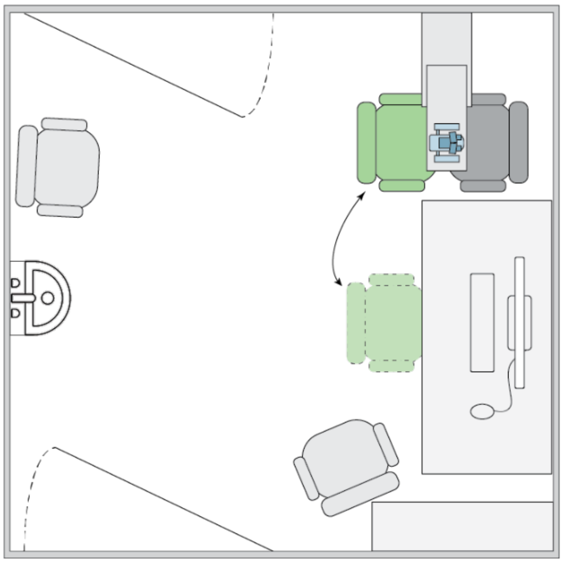
5: Patient in line with Ophthalmologist, on the right. Carers/companions behind.



6: Patient in line with Ophthalmologist, on the right. Carers/companions behind.



7: Patient in line with Ophthalmologist, on the right. Carers/companions behind.



8: Patient in line with Ophthalmologist, on the left. Carers/companions behind.

Figure 8-14: Maps of eight ophthalmological examination rooms, visited during the research phase

These maps are representative of ophthalmology practices in the Netherlands in general. When creating these maps I focused on the interaction points, so the tables, chairs, equipment, and the ophthalmologists' movement between them. Some other furniture is included for broader context.

Appendix 10 : Research Results: Observations and Interviews

This appendix includes transcripts of the observations and interviews conducted with the fourteen ophthalmologists during the research phase. Firstly, Table 8-4 shows respondent characteristics. Secondly, the observational study is described and elaborated on. Thirdly included in this appendix are transcripts of the interview answers, grouped in tables by their original question.

Table 8-4:Respondent results: Grouped by Research phase and sorted by Type of Institution

Institution	Resp. No.	Institution (1. Hospital, 2. ZBC, 3. UMC)	In training? (specialisation training)	Gender (m, v, x)	Years in the profession (incl. other employers)	Complaints in back/ shoulder/ neck	Complaints in hands/ wrists	Complaints in elbow
Research Phase 1								
IJsselland Ziekenhuis	1	1. Hospital		v	19		X	
Gelre Ziekenhuizen Appeldoorn	4	1. Hospital		m	11	X		
	5	1. Hospital		m	7.5	X		
Alrijne Ziekenhuis Leiderdorp	6	1. Hospital		v	22	X		
Eyescan Rijswijk	2	2. ZBC		v	13	X		
	3	2. ZBC		v	15			
Erasmus MC	7	3. UMC	x	v	2	X	X	
	8	3. UMC		v	14	X		
Research Phase 2								
Amphia Ziekenhuis Breda	9	1. Hospital	x	m	4	X		X
	10	1. Hospital		m	30	X		
	11	1. Hospital		v	18	X		
Franciscus Gasthuis / Vlietland	13	1. Hospital		m	22	X		
Xpert Clinics	14	2. ZBC		v	1.5	X	X	
UMC Utrecht	12	3. UMC		m	20			
			Total		**Average**	**Total**	**Total**	**Total**
			2		15,8	11	3	1

The graph below shows these results as they are presented in the main part of the report.

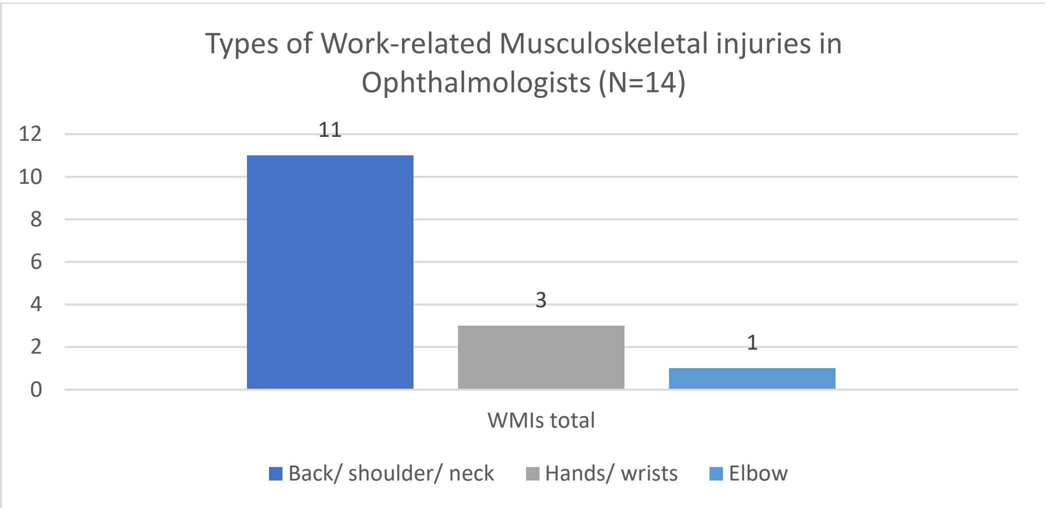


Figure 8-15: Types of WMI's in Ophthalmologists across 3 types of medical institutions

It can be concluded from table and graph above, that back, shoulder and neck complaints are by far the most common, with 11 out of 14 respondents reporting such complaints. Conversely, only 3 out of 14 respondents report complaints in the hands and wrists and 1 out of 14 reported complaints in complaints in the elbow. No correlation is observed between observed complaints and respondents' age nor type of institution, nor other observed characteristic.

Appendix 10.1: Observational prompt 1

The first research section was an observational study in the ophthalmic outpatient context. The first observational prompt is: *What type of chair does the ophthalmologist have?*
The pictures in Figure 8-16 show the variety of chairs used in clinics (lower number of chairs as compared to respondents are because of respondents' privacy preferences).

Figure 8-16: variety of Ophthalmologist's Chairs

As shown above, no similar type of chair is used across ophthalmic institutions. The type of seat used is mainly decided by preference, habit, or simply what chair appears to be available.

Appendix 10.1: Observational prompt 2

The second observational prompt is: *Does the layout of the room make the doctor turn around regularly during patient visits to talk to patients/supervisors or otherwise?*
Appendix 8Appendix 9 : includes maps of visited ophthalmic clinics. 4 out of 8 of these rooms are set up with the patient flanking the doctor. This makes them have to turn around regularly during patient visits to talk to patients. Additionally, in every one of these rooms, patient companions are seated behind the doctor, making the latter twist even further to talk to these people.

Appendix 8Appendix 9 : contains maps of 8 out of 14 clinics visited. The reason for not including maps of the remaining clinics is firstly, this observational prompt was added to the script through the course of phase 1. Second reason are privacy considerations.

Appendix 10.3: Observational prompt 3

The third observational prompt is: *Is the equipment (slit lamp) adjusted for good posture of the doctor? (if not, ask about this later)*.
8 out of the 14 ophthalmologists observed have their equipment set at a height that causes suboptimal spinal posture, either bending down, or overextending. Additionally, height differences between ophthalmologist and patient sometimes require the doctor to use an indirect ophthalmoscope, instead of a slit lamp, to examine the eyes.

Appendix 10.4: Observational prompt 4

The fourth observational prompt is: *Does the doctor adjust the slit lamp at the beginning of the day? Are further adjustments made throughout the day? For what reason?*
Only 2 of the 14 ophthalmologists make a conscious habit out of properly adjusting the table once in the morning and keeping it constant throughout the day. The rest make adjustments to it depending on patient proportions.

Appendix 10.5: Observational prompt 5

The fifth observational prompt is: *What brand is the Slit Lamp?*
Unequivocally the most used slit lamp model, used in 14 out of 14 ophthalmic rooms is a Haag Streit, model BQ900.

Appendix 16.6: Observational prompt 6

The sixth observational prompt is: *How do they use the separate lens during retinal checkups? Where do they rest their arm and hand? Is the lens and/or the elbow rest passed from hand to hand?*
All ophthalmologists rest their elbow during retinal checkups. Most often this is on an elbow rest. In 11 out of 14 cases, this is a foam pad present in the room. In 2 cases it is an improvised elbow rest as no foam pad is present (Figure 8-17). 1 ophthalmologist rests their elbow on the table, without elbow rest in between, as their arms are long enough to not need one.

The majority of ophthalmologists pass the lens from hand to hand when examining the patient's other eye, with only one being observed to use the same hand for both eyes.

Figure 8-17: An improvised elbow rest

Below are observations grouped by respondent.

Table 8-5: Interview Observations

	Observations
1	Doctor sits sideways to view both screen and patient, SL adjustments involve many turns of the wheels. Ophthalmologist has to reach up for taller patients as they themselves are shorter, extending their back far. Uses elbow pad in retinal checkups.

2	The chair for patient's companions/family stands behind the ophthalmologist. Because of this, the ophthalmologist has to turn around a lot. Ophthalmologist has to bend forward and down a lot to look into the eyepiece. Uses elbow pad in retinal checkups.
3	Ophthalmologist sits slightly bent forward. Uses elbow pad in retinal checkups.
4	Ophthalmologist needs to bend down a lot as they are significantly taller than the patients. Ophthalmologist has long enough arms not to need an elbow pad in retinal checks. Ophthalmologist has to use an indirect ophthalmoscope to examine a child patient, as slit lamp does not facilitate this difference in height. Using a slit lamp is preferred as it is more comfortable.
5	Ophthalmologist bends forward when using slit lamp. Uses elbow pad in retinal checkups.
6	Impersonal room, no windows either, small. Flex working. They only turn their neck and keep their back quite straight. Table seems to be very high. As a result, the forearms are raised, instead of flat. Uses elbow pad in retinal checkups.
7	Dark room, no windows, room is very deep, but SL is right next to the door. no elbow supports. 'you don't have enough time to do [preparatory work] during your working hours'. So they regularly have to prepare things at home in the evening. Uses improvised elbow pad in retinal checkups as no foam pad is present.
8	Ophthalmologist has to turn around a lot. Ophthalmologist is quite short, causing their shoulders to be tensed upwards to use the slit lamp.
9	Ophthalmologist mentioned in advance the eyepiece corner pieces and that they don't like that. Once again it is striking how divided opinions are about this. They are indeed twisted towards the patient. When using a dioptre lens, they sway sideways towards the lens, the back is no longer straight up but a bit to the right or left. Uses elbow pad in retinal checkups.
10	Ophthalmologist believes that you should be able to make your own choice of chair. Is not sitting straight towards the PC. Uses elbow pad in retinal checkups.
11	Ophthalmologist has to flex their wrist inward to adjust the SL. The patient is bent over, the doctor is sitting upright. Doctor bends her back to the right when checking retina. Keeps table stable throughout the day. Uses elbow pad in retinal checkups.
12	Ophthalmologist is bent sideways in retina checkup. They sit directly towards the patient during the conversation. He has to flex his wrist extensively to adjust the SL. He doesn't use the blue elbow supports, he has a metal box for them. The blue supports are there, but they say they prefer to use the box. Uses elbow pad in retinal checkups.
13	Slit Lamp is Haag Streit, '*I think 80% of the ophthalmology units have them in the Netherlands. They're the best quality*'. When he talks to the patient he turns completely. Not half twisted. Keeps table stable throughout the day. Uses improvised elbow pad in retinal checkups as no foam pad is present.
14	Posture is good. Feet flat, back straight, arms on the table. When working with slit lamp, their arms are always raised. Because of the table height, their arms cannot lie naturally.

The headers below include the answers to every interview question, starting with question 1.

Appendix 10.7: Interview question 1

Concluding from the table below, 11 out of the 14 ophthalmologists interviewed currently have some form of musculoskeletal injury.

Table 8-6: Interview question 1

	Do you have any lasting physical complaints? (expectation: muscle and joint complaints in the hands, wrists, back and neck)
1	Yes, prohibitive RSI in wrists/hands
2	No bad complaints myself, but radiating pain in the neck I don't exercise, also lower back pain
3	No
4	Yes, neck and shoulders problems
5	Yes, Recently visited physio for neck complaints and between shoulder blades
6	I had a frozen shoulder, now suffer from shoulder and upper back pain
7	Pain in neck and upper back. I've never been very attentive to it. Also slowly starting to experience pain in wrist when using a dioptre lens
8	Yes, neck
9	Yes, stiff neck after a busy day. I'm not going to get checked because then it will be in my file and then you won't be covered by insurance. My elbow was bothering me for a while, due to leaning too much on the hard wooden surface.
10	Wrist pain but not structural. When measuring eye pressure you have to look around the SL, and that does bother me. I'd rather sit there all day. I have no predisposition for physical complaints
11	Had neck problems, but after physiotherapy it suddenly disappeared. After a busy day, neck and shoulders ache. Tense neck, you notice that when you lie down in bed that you relax. When it's really busy I get more physical complaints
12	None, I've little predisposition for it. I have a slender build
13	Definitely did. At one point my shoulders were so tight that I couldn't even get the parking ticket out of the machine. But with more exercise, twice a week, this completely disappeared
14	Stiff neck shoulders, hands cramp

Appendix 10.8: Interview question 2

Concluding from the table below, 11 out of the 13 ophthalmologists agree that the complaints are tied to the work.

Table 8-7: Interview question 2

	Are these related to your work, and/or do you see a connection between your work and these problems?
1	Absolutely
2	Partly yes
3	[no complaints]
4	Absolutely
5	Poor posture, sitting forward
6	Unsure, but the time pressure also gives bad posture
7	'You just don't have time for your ergonomics'
8	Yes
9	Yes
10	Yes

11	Yes
12	[no complaints]
13	Yes
14	Yes

Appendix 10.9: Interview question 3

Concluding from the table below, no correlation is currently observed on starting point of complaints.

Table 8-8: Interview question 3

	When did these start? Early in your career or did it take a while?
1	A few years ago
2	Not sure
3	[no complaints]
4	After a few years as a specialist
5	Within a few weeks, SL table could not move. Not a good upright posture anyway
6	[no complaints]
7	It already started a bit during studying, and this work just reinforces it.
8	Not sure
9	It builds up. Nothing permanent yet, but a stiff, painful neck after a busy day.
10	[no complaints], Work pressure does make me a bit rigid
11	[no complaints]
12	[no complaints]
13	After some years
14	It's stable now, used to be worse. I went to a physiotherapist. I also exercised intensively at that time. I didn't do much cooling down during the intense exercise, I paid less attention"

Appendix 10.10: Interview question 4

Concluding from the table below, ophthalmologists interviewed mention small hand movements; giving priority away to the patient and neglecting personal ergonomics in the process; awkward posture during retinal checkups; work pressure; insufficient equipment adjustability & inability to adjust equipment to height differences between patient and doctor, as causes for work-related musculoskeletal injuries.

Table 8-9: Interview question 4

	What do you think is the cause of these problems? Or what is the biggest cause?
1	The small movements and adjustments on the slit lamp
2	it's simply in the profession,
3	colleagues adjust everything for patient comfort, making them super uncomfortable
4	concentration makes you bend forward, A bad night's sleep can suddenly make things worse
5	personally suffer most after laser treatments, with patients you sit there holding a lens forward for minutes, a lot of it is that you just do injections all morning, there are also many different, clumsy movements and positions. During surgery, your muscles cramp really quickly, Tension, concentration. What also doesn't help is that we have to do more and more administration

6	More common in women, they say, as they get older. Yet that stress, pressure, tension, is due to busyness, and also that you have to remain nice
7	Not a straight neck, the eyepiece doesn't fit well, so I have to bend my head forward + eyes forward, not comfortable/ergonomic. That wrist that is always bent back when using a dioptre lens is not nice, they think that this may be less of a problem for people with larger hands.
8	consultation hours are full by default', 1:00 PM to 3:30 PM is consultation hours, but this also includes telephone appointments that often take even longer. Tension in the OR also causes bad posture. Long operations make things worse. Many patients. I said hope we can come up with a solution, they said: 'fewer patients'
9	If you are sitting correctly, your patient will be dangling. If you are very focused, you will also sit poorly. He also says that he sits a bit forward because he is quite small, his right foot is not straight on the ground but bent under him. He mentioned at the beginning that if you move the SL forward (towards the patient) you go after it, and then you suddenly find yourself bent over. Without asking, he mentions that the SL is difficult to adjust for comfort for both the patient and the doctor. Work pressure and difficult patients still cause you to make mistakes. For short patients, you sit forward, hunchbacked. Focus ensures that you no longer pay attention to your posture or notice your own incorrect posture
10	[no complaints]
11	That stiff neck can happen on busy days
12	[no complaints]
13	With that static position, shoulders, back and arms under tension, you build up those complaints. That tension resonates. We talked about Dioptre lenses. He uses a 79 Dioptre lens, which he thinks is best. It is a bit larger than a 90 dioptre lens that I have seen before, and you have a slightly larger image. I asked, what is the advantage of a 90D, with a smaller image, and he said yes, no idea. *'I think automatism and habituation. Ophthalmologists often have strong automatisms [...]. They don't like changes.'*
14	Repetitive work, you don't sit straight and workplace ergonomics

Appendix 10.11: Interview question 5

Concluding from the table below, all ophthalmologists interviewed have colleagues that have work-related musculoskeletal injuries.

Table 8-10: Interview question 5

	Do you have colleagues to whom this also applies? (that have work-related musculoskeletal injuries)
1	It is wide spread
2	of course
3	yes
4	many
5	resigned bc of neck hernia, other operated several times, At clinics, many procedures are outsourced, which means you see fewer complaints.
6	Yes. I also think that more men suffer from neck problems due to height
7	I already heard from a colleague with a neck hernia. I think doctors who also operate often pay more attention to good posture.
8	Sure yes
9	Definitely
10	Of course

11	Colleague had neck hernia (surgery), 2 other former colleagues also had neck injuries. [...] also had a back injury, hernia
12	absolutely
13	Of course
14	Of course

Appendix 10.12: Interview question 6

Concluding from the table below, regular exercise is a recurring remedy and prevention for work-related musculoskeletal injuries, straight posture is also mentioned, but rarely adhered to structurally.

Table 8-11: Interview question 6

	What do you do yourself to (try to) prevent, reduce and/or remedy these problems?
1	I now have lighter lubricant oil in my SL to reduce the force
2	Regular exercise, if I don't the problems get worse
3	[no complaints]
4	Sports, regular massage
5	Physio exercises, but you quickly stop doing them when you're fine again. For a simple eye pressure check for which patients have already been to the optometrist, I will not look into their eyes again to make it less straining. Also due to the workload, I no longer get up at the start of a consultation, to consciously minimize movements.
6	We rotate work spaces, so little time to properly adjust the equipment. You do what you can, but it is never really optimal. What is good about rotating is that you not only always have 'the bad room', but also not always 'the good room'. I think rotating is an advantage because you don't always sit and work in the same way/room, and that even though you don't have everything tailored to yourself, that is an advantage.
7	Not much
8	Seat lower, feet on the floor
9	Try to sit properly and straight, but you quickly forget
10	He uses a yellow lens to protect his retina
11	I actually forget that
12	Exercise a lot. Good ergo operating chair (saddle-like with armrests). In the outpatient clinic it is just a simple stool
13	When I work here, I adjust the table completely to myself, and then the patient's chair depending on that. Going to the gym twice a week
14	To play sports, and I've been to a physiotherapist

Appendix 10.13: Interview question 7

Concluding from the table below, among ophthalmologists interviewed, are generally unsure of how to best adjust the equipment and their posture properly. Some do not adjust as they have not complaints, some do, but aren't sure if they do it correctly.

Table 8-12: Interview question 7

	Is the equipment properly adjusted to you right now? When do you adjust the slit lamp and surrounding equipment? For what reason?
9	No time for that
10	I have no complaints, it's fine

11	I'm not sure if I do it right
12	No complaints, I just make sure I can see the eyes. Wouldn't know how else to do it better.
13	Yes, as I arrive early every day to adjust the equipment
14	I generally don't adjust much. I also find it difficult to know what is good. You don't know what is proper posture. See you don't have any complaints right away and you can't see yourself either while you're in bad posture.

Appendix 10.14: Interview question 7b

Concluding from the table below, 5 out of 7 ophthalmologists that answered this question do not adjust the equipment to themselves, but more to the patient.

While question 7b was not asked with respondent 8 as they were during phase 1, their comments form answers to the question, so they are included between parentheses.

Table 8-13: Interview question 7b

	Do you adjust the slit lamp and other equipment more to your own comfort or the patient's?
[8]	I really adapt [the SL and chairs] to the patient
9	If you are sitting correctly, your patient will be dangling. If you are very focused, you will also sit poorly. I am quite small, so my right foot is not straight on the ground. If you move the SL forward (towards the patient) you go after it, and then you suddenly find yourself bent over.
10	Previous answer: I have no complaints, it's fine
11	I try to adjust their height to my own comfort, sometimes it's just not possible
12	I have no complaints, so I just make sure I can see the eyes. Don't mind if I have to bend a bit
13	To me, I have to work like this for decades. They're here for 5 minutes, so I prioritise myself.
14	Best would be to focus on me, but if they're shorter or taller than me, I adjust it to the patient. We have a hard cushion for the patient chair for a better fit. I also think 'oh it's just for a little while, it's fine'

Appendix 10.15: Interview question 8

Concluding from the table below, ergonomic support in ophthalmic institutions is rare.

Table 8-14: Interview question 8

	Have you had contact with ergonomists, physiotherapists or other professionals from within the organization or on your own initiative who offer help with this?
1	I haven't
2	[no complaints]
3	We have an ergonomist in house, on maternity leave.
4	Support staff were the first to complain, then the doctors followed, but no ergonomists or anything have gotten involved.
5	No, I know the problem and what to do but I just have to do it myself
6	No
7	I don't know
8	I have not
9	I will not go to a specialist for it because the insurance will no longer cover you. My spouse is a dentist and had this. With minor problems with their little finger joint, all joint complaints are no longer covered by insurance.

10	[no complaints]
11	We are not officially employed as ophthalmologists. Officially we are independent, so little happens from an organizational perspective. You can request or raise certain things, but that is not standard.
12	[no complaints]
13	Originally when I had the shoulder complaint yes
14	No

Appendix 10.16: Interview question 9

Concluding from the table below, some ergonomic interventions were introduced: eyepiece corner pieces, elbow rests, adjustable tables and patient chairs. No sufficient working situation has been created yet though.

Table 8-15: Interview question 9

	Has there been a change in approach (of ergonomics and comfortable long term working conditions) over time in your organisation and the sector as a whole?
1	We now have elbow rests to reduce shoulder strain
2	You have corner pieces for the slit lamp. It would feel strange, probably because I'm not used to it
3	Not sure
4	High low table has been standard in recent years
5	Not with current employer. For example, everyone also has a different chair. No clear policy. It would be nice if advice was given on this.
6	More and more people are dropping out, it's getting busier. The average is 18 patients in the afternoon and 17 in the morning. They now have better chairs, at first they were large, cumbersome chairs that could not be moved, especially because they're quite small
7	Since 2019, the adjustable (SL) table, SL table and work desk are one unit that move together
8	Not sure
9	Not sure
10	Yes, more automation, it is much better now
11	Chairs are new but not always optimal. Digital screens cannot always be set. Modern, digital patient files mean that you have to look back and forth more often.
12	The equipment is in need of replacement, they are going to renovate the entire clinic soon
13	We recently switched to LED light with the slit lamps
14	This clinic has only been open for six months, so it has modern technology. Moving desks. Corner piece, curved cushions, high-low tables, adjustable patient chairs. Everything can be positioned better during surgery

Appendix 10.17: Interview question 10

Concluding from the table below, respondents are unaware of any coherent guidelines on ergonomic working.

Table 8-16: Interview question 10

	Are there any guidelines for the proper ergonomic use of the workspace in favour of longtime wellbeing?
9	Not aware of any
10	Not aware of any
11	Not aware of any
12	Not aware of any

13	Not aware of any
14	Not aware of any

Appendix 10.18: Interview question 11

Concluding from the table below, respondents have little insight into prevalence of work-related musculoskeletal injuries in adjacent professions.

Table 8-17: Interview question 11

	Do you have insight into how this [prevalence of work-related musculoskeletal injuries] is different in adjacent professions? Such as Opticians, Optometrists, (any others?)
1	No insight
2	No insight
3	No insight
4	No insight
5	I don't know, but they see fewer people, half in a day
6	The ophthalmologist is ultimately responsible, so the pressure is clearly higher. They also mention that in their role they have the feeling they can help people, more than as an optician, for example, so that also makes it fun.
7	No insight
8	No insight
9	I think less there, but you should check. I think that is also the case with the doctor because it is so busy.
10	No insight
11	No insight
12	No insight
13	No insight
14	No insight

Appendix 10.19: Interview question 12

Concluding from the table below, varied negative responses and opinions were recorded on the current equipment.

While question 12 was not asked with respondent 6 and 7 as they were during phase 1, their comments form answers to the question, so they are included between parentheses.

Table 8-18: Interview question 12

	What is the most annoying thing about the device? (is there anything that you want to change?)
[6]	It sometimes doesn't run smoothly, but that is also checked up on regularly. The rubber around the joystick is sometimes loose because some doctors prefer to remove it than others. They find it difficult to say what is wrong with it
[7]	I don't like the angle of the eyepiece. You have to look straight into it. Slightly downwards would be nicer, but we don't have that possibility. It would be nice to be able to click the corner piece on and off, instead of the current strenuous twist motion. It would be even better if the eyepiece had a variable angle.
9	It is strange that you move the entire SL, including the eyepiece, when you look at the eye. This means that you also have to move with the eyepiece, while it would be nice if it remained stable. It would be so nice if everything on the ophthalmologist side was stable and not moving.

	Then you can adjust it perfectly for yourself. If you work with mirrors or something digital or whatever, you can adjust on the patient side. That means you 'disconnect' the 2 sides.
10	Retinal check-ups with the separate lens are not convenient. Light conditions are poor. I recently purchased some desk lamps to see better and to be less burdened by the bright outside light.
11	This is my own room (shared with 1 other person), so much is well adjusted. Wouldn't be the case in another room.
12	That splash screen that was added after covid, I'm constantly hitting it. The patient sometimes trips over the chair base. The equipment is old, but it will last a long time.
13	Nothing in ophthalmology is standard. You often press 1 button, the table moves forward, the SL lamp turns on, the lights are dimmed, and you're done. With the unit here, you press a button to release the magnet and you have to physically pull the table into place. not very ergonomic. If this swivel table, with its flexibility, also had those automations, button -> table moves motorized, SL on, room lights off, then this would be better. I would also like more unity between different rooms and locations
14	There is also a camera on the SL in Zeist [the other location they work at], which may not be necessary. Other than that I don't know

Appendix 10.20: Interview question 13

Concluding from the table below, varied positive responses and opinions were recorded on the current equipment.

While question 13 was not asked with respondent 6 and 7 as they were during phase 1, their comments form answers to the question, so they are included between parentheses.

Table 8-19: Interview question 13

	What is the most useful aspect of this device (Slit lamp and surrounding equipment) that should not change?
[6]	I like that everything is mechanical and can be easily adjusted, compared to other brands where everything is thicker and/or more automatic. Robust, firmly constructed, easy to keep clean.
[7]	The slit lamp can be adjusted simply and smoothly with the lever
9	I'm not sure
10	There is a variety in quality of slit lamps. Haag Streit BQ900 is the Rolls Royce, that's what we work with. Other areas have mid-quality slit lamps. The other slit lamps are either old versions or a different brand. You notice it in the clarity of the image, which is lower with those alternatives.
11	Functionalities must remain the same. I actually don't like the side viewer because it's close to your face, so if a resident is observing your examination, they are really close to your face. You could also do that with a camera or TV. Completely automated on a screen would be great.
12	I'm not sure
13	Haag Streit is simply the best. Quality is the highest. Light, image, lenses, just like with a good camera, you just notice the difference.
14	I'm not sure

Appendix 10.21: Interview question 14

Concluding from the table below, the consensus among respondents appears to be that the corner piece is only appropriate for tall doctors.

Table 8-20: Interview question 14

	What do you think about the direction of the eyepiece? What is your opinion on the corner piece to change the direction of the eyepiece?
9	I don't need the corner piece as I'm quite short
10	I don't like the corner piece myself, I'm not tall enough for that
11	I don't like the corner piece, I'm already quite small, and then you sit completely bent over. I like it straight.
12	I'm doing fine without it
13	I'm not that tall, so a corner piece like that isn't necessary for me. I like to take the time (20 seconds) to remove the corner piece
14	With a corner piece I'd have to sit even higher. Also, you often have to go look for that corner piece as it isn't always present in the room.

Appendix 10.22: Interview question 15

Concluding from the table below, the amount of supporting staff present (TOA'sas, optometrists, and residents), appears to change the amount and nature of the work pressure. More supporting staff seems to result in fewer physical complaints for the ophthalmologist. However, the higher degree of responsibility, and more managerial duties seems to add its own sense of pressure to the ophthalmologist's work.

While this correlation between working pressure, amount of supporting staff and work-related musculoskeletal injuries experienced, is claimed by some respondents, this cannot be unequivocally confirmed.

Table 8-21: Interview question 15

	Do you experience a high working pressure, and does this change depending on how much supporting staff (such as TOA's or optometrists) is present?
[6]	Lot of work is delegated to support staff, and they also mention that they have few complaints
9	I'm not sure
10	Yes, the more support, the fewer complaints and pressure itself. It's a luxury to have that support. Also depends on budget
11	No connection
12	I don't know
13	I'm not sure if those are connected
14	Yes, I think that the stress of doing everything alone also contributes to complaints. Less support also means more workload. Average is 17 to 19 patients per day. Not such a direct connection, but if you provide that support well, it can reduce the workload. This means you will have fewer complaints

Appendix 10.23: Reflection

The observational findings and interview answers were used to form the list of requirements and preferences, as described in List of Requirements and preferences.

To this end, the observational and interview results were first combined into a list of compiled results, included in the next Appendix (8Appendix 11 :).

Appendix 11 : Compiled results

Previous appendix 8Appendix 10 : includes the research results per observational prompt and interview question. These results were combined in the list below. This list formed the step from individual script results, to answering the research questions.

1. The majority of ophthalmologists' work-related physical complaints are in the shoulders, upper back, and neck (11/14). Hand and wrist complaints are reported occasionally (3/14).
   1.1. Every single ophthalmologist I spoke to, either has or has had these musculoskeletal complaints, or if not themselves, have colleagues that do. This applies across all demographics. The ubiquity of these complaints is confirmed by literature such as Kitzmann et al (2012), Al-Rashed (2016) and Kaup et al (2018). These sources also confirm the higher prevalence of upper-spine complaints, over the less prevalent upper extremities complaints (hands, wrists, fingers).
2. The majority of ophthalmologists work in a suboptimal way in terms of ergonomics, even though many of them are aware of the problem. This is caused by several factors.
   2.1. Waiting lists for patients to get an appointment are long and the typical ophthalmological consultation does not last longer than 10 minutes. These two factors put the ophthalmologists under <u>time pressure</u> to meet the demand.
      2.1.1. This pressure to perform reduces the <u>time, necessary</u> to adjust the equipment to the comfort and wellbeing of the doctor.
      2.1.2. The work pressure also increases, <u>cognitive load and mental</u> stress. Both factors which have been identified as contributing to neck pain. (Anderson et al., 1997)
   2.2. Many ophthalmologists work interchangeably between <u>different rooms</u> within their institution (this applies to all 3 types of medical institutions).
   2.3. Lack of equipment adjustability for ergonomic usage is a common complaint (unchangeable height of table/chair/slit lamp; unchangeable eyepiece angle, inability to accommodate wheelchair users).
      2.3.1. Additionally, <u>wheelchair users</u> can rarely be accommodated for as the slit lamp table's range of motion is lacking. The two current solutions here are either, for the wheelchair user to move into the fixed, patient chair. This is often with a lot of assistance from either the ophthalmologist (putting pressure on them) or supporting family members/carers. The second option is using an indirect ophthalmoscope. This is a handheld, slit-lamp-like device, used alongside a handheld lens to examine the eyes (See Figure 8-18). These devices are held mid-air by the doctor, which as Fethke et al. (2015) states, puts the highest degree of strain on their arms and shoulders out of all ophthalmic equipment used.
   2.4. Training on ergonomic working and long-term health in ophthalmic specialisation education is sparing, as confirmed in my interviews. Motmans (2022a) also mentions this saying: '[Work method and ergonomics] *are discussed in various medical courses, but not yet in a structured way.*'. Ratzlaff et al. (2019) furthermore confirms '*a promising ability for an educational module to mitigate some injury risk in this population during indirect slit lamp examination*'. This absence of ergonomical training is contrary to other specialisations like dentistry, where emphasis on this aspect is much greater (Dental Ergonomics, 2018).


Figure 8-18: (left) Doctor examining patient with indirect ophthalmoscope
Figure 8-19: (right) Ophthalmologist working with twisted spinal posture, even after patient has left

3. Ophthalmologists often adjust the equipment or their behaviour to their patients' needs, instead of their own.
    3.1. A common problem arises from a difference in height between the patient and the ophthalmologist. Several subproblems arise from this.
        3.1.1. The doctor's chair might be set to a suboptimal height causing bad leg posture. Optimal leg posture means feet flat on the ground (Kent, 2011) and 90° angles between torso & upper leg and between upper leg & lower leg (Hyer et al., 2015).
        3.1.2. The table that the slit lamp is on might be set to a suboptimal height, causing stress in the shoulders and arms. Optimal table posture enables the user to rest their arms on the table with a 90-degree angle between upper and lower arm (Motmans, 2022c).
        3.1.3. The eyepiece can end up at a height that is uncomfortable for the doctor. Because of this the doctor might develop bad spinal posture by bending forward/down to look through the eyepiece or having to overextend their neck to reach up to it. Optimal spinal posture means head, neck and torso are vertically aligned (Honavar, 2017).
    3.2. Many ophthalmologists twist towards or away from the patient when they are talking and writing at the same time. The resulting spinal flexion is connected to MSD's (Algarni & Alkhaldi, 2021). The most ergonomically optimal way of working behind a desk is sitting straight up, facing straight towards the screen (Mayo Clinic, 2023). The spinal flexion is due to two reasons.
        3.2.1. Social norms dictate we face someone when we talk to them.
        3.2.2. Many ophthalmology rooms are set in a way that requires the doctor's spinal flexion to look at them. The patient is often sat perpendicular and/or entirely to the side of the doctor. (see Clinic maps, for further elaboration).
    3.3. Lastly, there are instances where the patient's height or stature is so different to the ophthalmologist's, that the equipment does have to be adjusted to be used effectively. This results in bad posture for the doctor and the before mentioned time pressure might not allow the ophthalmologist to readjust the equipment back to their own comfort after said patient.
4. A common procedure during ophthalmic consultation is a retinal check-up using a separate lens that is manually positioned between the patient's eye and the slit lamp.
    4.1. Holding this lens up puts strain on the hands, arms, and shoulders (Kent, 2011).
    4.2. Nearly every ophthalmologist now has an elbow support pad to relieve some of the stress, but the rest of the arm still hovers largely unsupported. Additionally, if the doctor' arm is long enough not to need the elbow rest, it rests on the hard table, which can also lead to MSDs over time, as mentioned by one of the visited ophthalmologists and Kent (2011).

4.3. The pad is loose and has to be physically moved to the other side of the slit lamp when switching to the patient's other eye. The same applies to the lens itself, which also changes from one hand to the other when examining the patient's second eye.

Figure 8-20: (left) Ophthalmologist using separate lens for funduscopy
Figure 8-21: (right) Elbow support pads

5. The <u>different stakeholders</u> surrounding the slit lamp make for a complicated context.
   5.1. The party purchasing the equipment (management and medical purchasing), is different from the party using it (ophthalmologists, as well as optometrists). While the doctors have an active voice in the buying process, it is only one of the voices among a number of different opinions and considerations. This leads to a discrepancy as needs and preferences do not always line up.
   5.2. When the context is a hospital, there is another set of parties that are responsible for vetting electrical equipment that comes into the institution along institutional and legal guidelines. This last process not only lengthens the introduction time, but also increases the costs, associated with introducing new equipment.

The list and table above formed the step from individual script results, to answering the research questions. Result 1 formed the answer to the research question 1. Result 2 through 2.1.2 provide context factors for the project. Result 2.2 is used to answer research question 2c. Result 2.3 is used to answer research question 2a. Result 2.4 is used to answer research question 4. Results 3 through 3.2 are used to answer research questions 2a and 2b. Result 3.3 provides a context factors for the project. Results 4 through 4.3 is used to answer research question 2a. Results 5 through 5.2 provides a context factors for the project

Appendix 12 : List of Requirements and preferences

This appendix includes the full list of concept requirements and preferences. The list of requirements and preferences was drawn from the research conclusions as well as expected requirements of an industrially produced product. In this list, *requirements* are hard necessities for the concept to meet, and *preferences* are lower priority points to address. The origin of every requirement is mentioned under them individually.

Requirements - Project Brief

1. The concept improves the wellbeing of Ophthalmologists by improving one or multiple aspects of the physical ergonomics of their daily activities in the outpatient clinic
   [Reason: Main project goal]
2. The experience for patients being treated, diagnosed or otherwise interacted with, through the use of the new concept by the ophthalmologist, is equal or better than currently
   [Reason: Ophthalmologists already prioritise their patients' comfort over their own health in the current context. If the concept is to be successful, it must at least keep the patient's experience equal to the current experience.]

Requirements – Feasibility

Can it be done?

3. The concept fits within the context of Dutch Ophthalmology institutions and the ophthalmological outpatient clinic in terms of measurements, visual characteristics and auditory experience
   [Reason: as mentioned by one of the supplier representatives at the NOG conference (Appendix 8Appendix 21 :), equipment is often fit to the existing room, regardless of whether it is ergonomically optimal or not. The design therefore, will have to work within the existing space, to be successful.]
4. The concept meets the expected requirements of an industrially produced product
   [Reason: When the concept is developed further, these are requirements to be aware of.]
   4.1. The concept can be produced with common production methods
   4.2. The concept consists of commodity materials and components
   4.3. The concept can be cleaned for medical purposes
      4.3.1. The concept is water resistant
      4.3.2. The concept is not affected by common cleaning solutions such as disinfecting alcohol
      4.3.3. The concept has no hard-to-clean cracks, creases or corners
   4.4. The concept can be disassembled for maintenance

Requirements - Desirability

Does it address the users' values and needs?

5. The concept is designed in such a way that the users feel naturally inclined to incorporate it into their routine.
   [Reason: The medical sector of ophthalmology is a conservative one. This was confirmed in different stages of the project, including the pre-research visit to the medical instrument technician (Appendix 0), the research Interviews, and at the NOG conference (Appendix 8Appendix 21 :). Keeping this context in mind, the concept needs to be designed in such a way, as to be minimally intrusive and maximally easy-to-adopt for the users.]
   5.1. The concept use is intuitive,
      5.1.1. The concept is taken to be intuitive along the description given by IDF (2024): 'when a user is able to understand and use a design immediately—that is, without consciously thinking about how to do it—we describe the design as "intuitive" '. The user should therefore be able to use the concept effectively with little to no instruction or training.

5.2. Where possible, interactions are kept familiar.
    5.2.1. When new interactions are introduced, they are paired with an existing interaction, to ease adoption.
    5.2.2. New and different interactions are justified by significant improvements in ergonomics, ease of use, or duration of use
5.3. The concept is comfortable to use
5.4. The concept takes the same or less amount of time to use as its current alternative
    5.4.1. If introducing a new action, this is justified by its benefits
    5.4.2. Or, if it takes longer, it justifies this by reducing time spent on other actions
5.5. The concept can be installed by medical technicians with less than [*30 minutes*] additional training

6. The concept provides the same basic functionalities as the current alternative
   [Reason: This requirement stems largely from the same reason as the last (5.), which is conservatism. If the concept provides, at least, the same functionalities as the current alternative, but does so in a way that inherently improves the user's posture/health, it is more likely to be adopted.]

Requirements - Viability

Will it survive long-term?

7. The concept's purchase cost fits within medical institutions' budgets
   [Reason: In this medical context, the users that benefit from the concept, the ophthalmologists, are not the ones purchasing the equipment, and while they have an important say in this process, the final verdict in the hands of their employers. Cost therefore, is an even more important factor.]
8. The useful product lifetime of the concept is comparable or longer than existing alternatives
   [Reason: Current alternatives are installed to be used for the order of magnitude of 10 years. As these alternatives are a long term investment for medical institutions, this needs to be considered, and catered to.]

Requirements - Concept

9. The patient's chair moves and accelerates faster than the current alternative
   [Reason: If the chair were to move along its new range of motion with the speed of current alternatives, this would take almost a full minute, which is too long for the fast paced ophthalmic context]
   9.1. Speed is built up gradually and eased down gradually at the end
   [Reason: This specified requirement corresponds to broader requirement 2, stating that patient experience needs to be maintained.]
10. The full concept guides the ophthalmologist in height adjustments and takes time commitment in decision making about these adjustments away from the user as much as possible.
    [Reason: This specified requirement corresponds to broader requirement 5.4., stating that The concept takes the same or less amount of time to use as its current alternative.]
11. The most used buttons are closest to the user; buttons are grouped by functionality and what they control; and size and position of buttons convey their function.
    [Reason: Current interfaces place buttons in an unintelligible grid, by adhering to these guidelines, initial adoption can be sped up.]

Preferences

1. The concept is designed for long term use. It thus does not have a throw-away nature and does not increase material waste
   [Reason: This preference is based on sustainability considerations.]
2. The concept can be repaired and/or reused and/or refurbished and/or recycled upon breakage at the end of its useful life

[Reason: This preference is based on sustainability considerations.]

3. The concept is low cost, to make it more likely that medical institutions will adopt it
   [Reason: A concept that improves ergonomics for employees at a lower price point makes adoption by medical institutions more likely]
4. The concept's usefulness extends beyond ophthalmology and also benefits bordering professions like optometrists and opticians
   [Reason: Some ophthalmic equipment is used beyond ophthalmology in other eye-health related professions. Of the concept improves upon one of these pieces of equipment with a broader use, this could increase its potential.]

These requirements and preferences may be referred to henceforth in the rest of the report as (Req. [number]), and (Pref. [number]).

Appendix 13 : From research conclusions to design directions

In this appendix, I will illustrate the process in which I went from research conclusions to design directions. I started by distilling the compiled results from Appendix 8Appendix 11 : (left in figure below) into underlying sub-problems. I categorised these by the three categories of risk factors contributing to physical complaints, that I identified for my research sub-questions (right in figure below). These categories of risk factors are indicated in the figure below as Green: physical, Red: logistical, and Purple: behavioural.

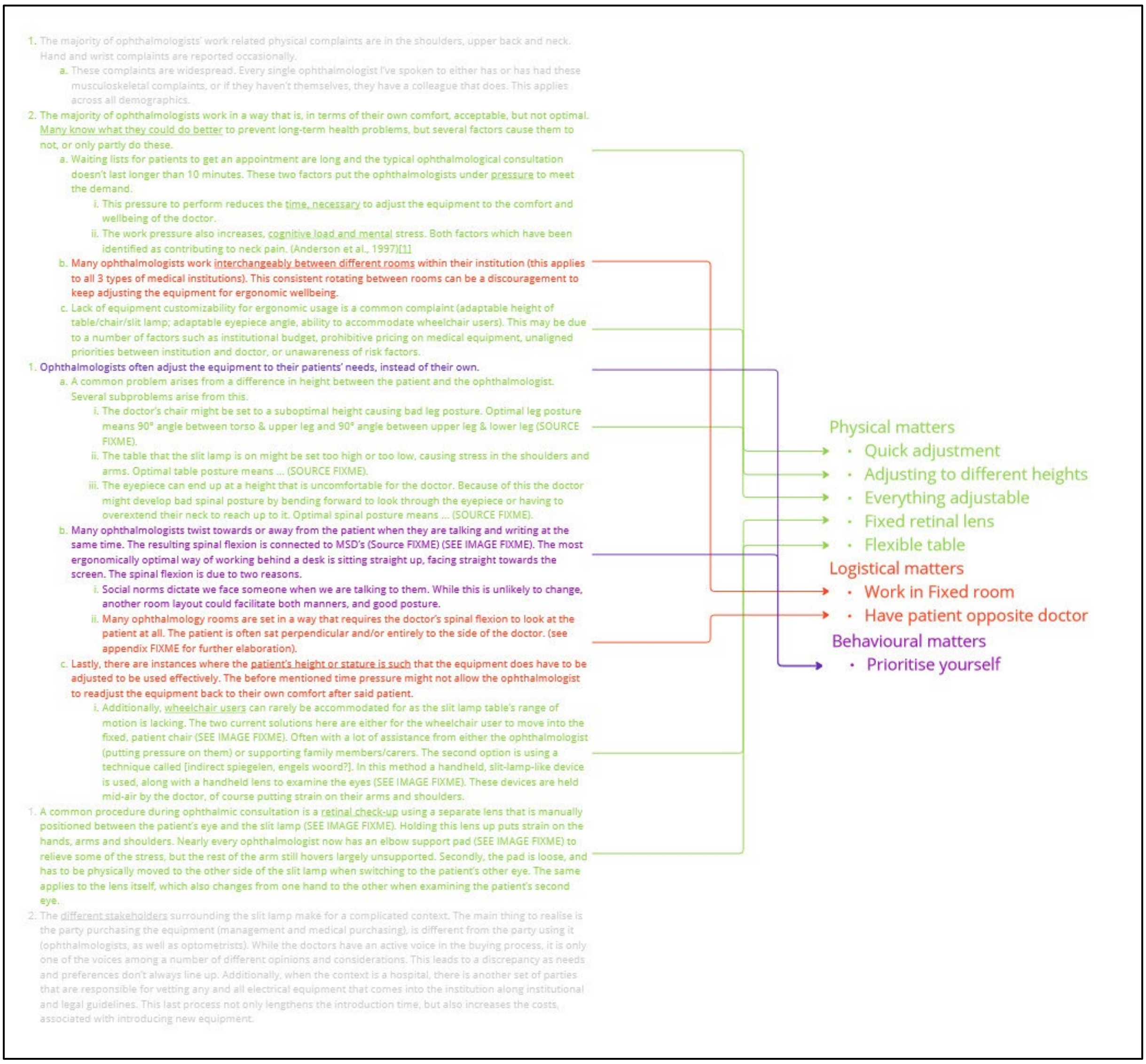


Figure 8-22: Process from research conclusions (Left) to solution spaces (Right)

The logistical and behavioural matters are used as important context factors for the design phase, and are later used to give advice for the current context in chapter 5. The physical sub-problems were further grouped until they formed the 2 main problem spaces for this project, as shown in the figure below.

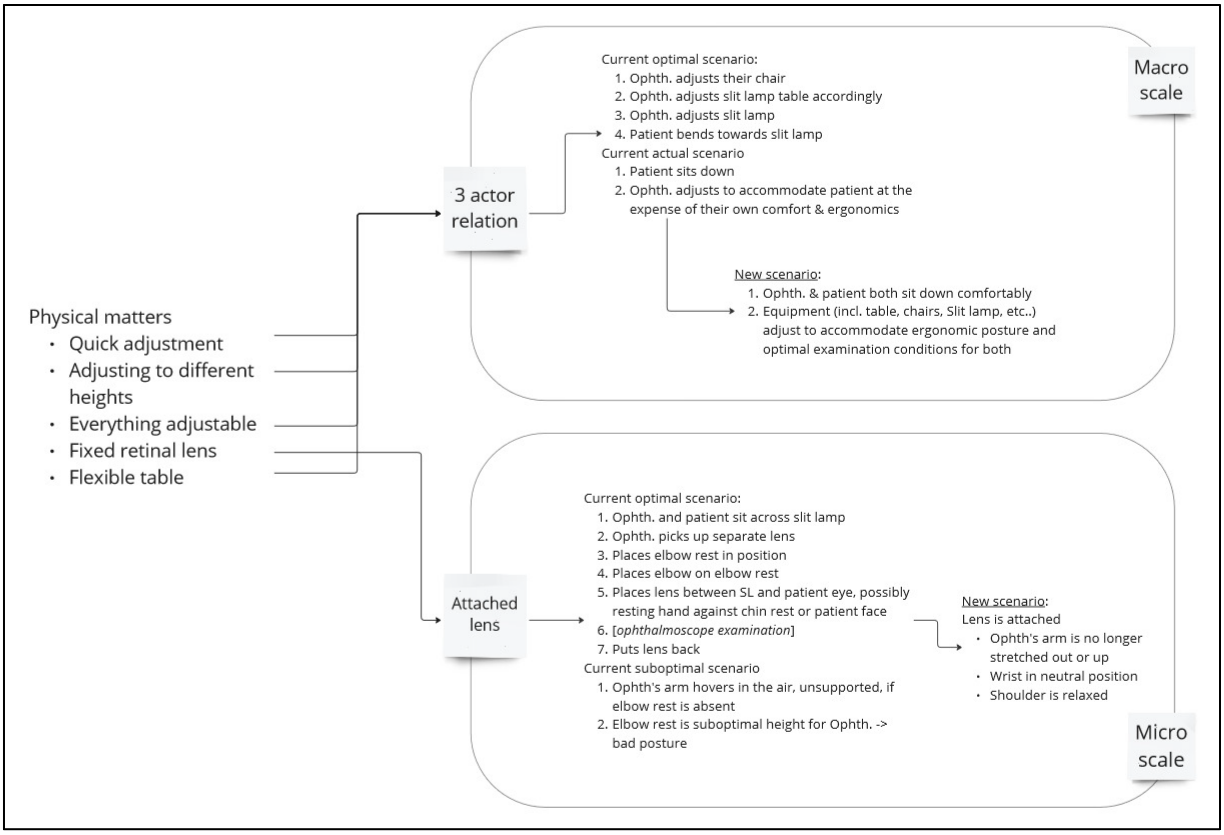


Figure 8-23: Process from solution spaces to design directions

The two main problem spaces to carry on with henceforth, are Problem space 1: Position of Ophthalmologist, Patient and Equipment ('3 actor relation' in the figure), and Problem space 2: Positioning of the retinal lens ('attached lens' in the figure).

Appendix 14 : Decision-making: Harris Profiles

In this appendix, I will describe the decision making process after the initial ideation stage, to decide on the solution to further develop. Harris profiles were used to make more objective choices based on requirements.

I will first introduce the 10 solution ideas to be judged. The solutions are introduced and explained, assuming the reader's knowledge of the four design sub-directions from Chapter 4.3.

These directions are:

- Direction A: Redirecting the Picture
- Direction B: Aligning Doctor and Patient
- Direction C: Attaching Retinal lens to Slit lamp
- Direction D: Attaching retinal lens to Patient

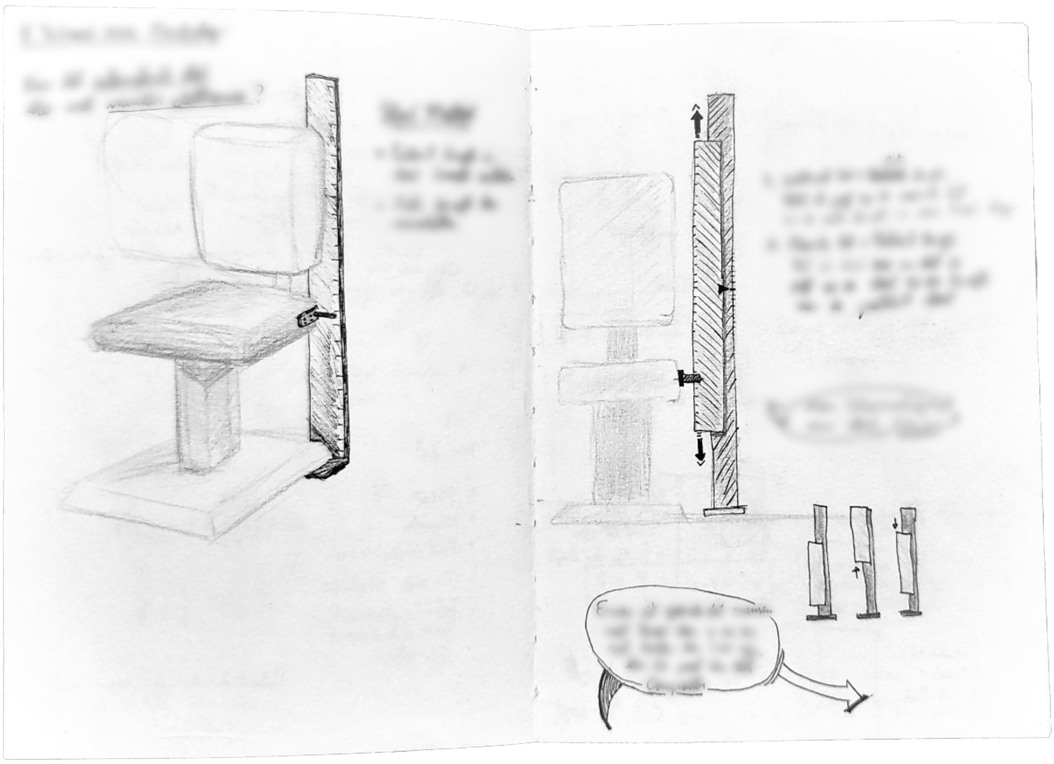


Figure 8-24: Solution idea 1: Height Slider

Height Slider (Figure 8-24) is a solution in Direction B: Aligning Doctor and Patient. It is a non-electronic addition to the existing patient chair in an ophthalmic outpatient clinic examination room. In the figure, the initial version on the left, is followed by the improved version to the right. It is this right version that is included in the Harris profile as it provides more functionality. The standing measuring stick represents the height of the doctor. The second measuring stick attached to this represents the height of the patient. This second stick is slid along the stander until the peg on its side indicates the doctor's height on the primary standing measuring stick. The patient chair is then changed in height until the peg on its side indicates the patient's height on the second measuring stick. When relative measurements are applied properly, the doctor and patient can both sit ergonomically.

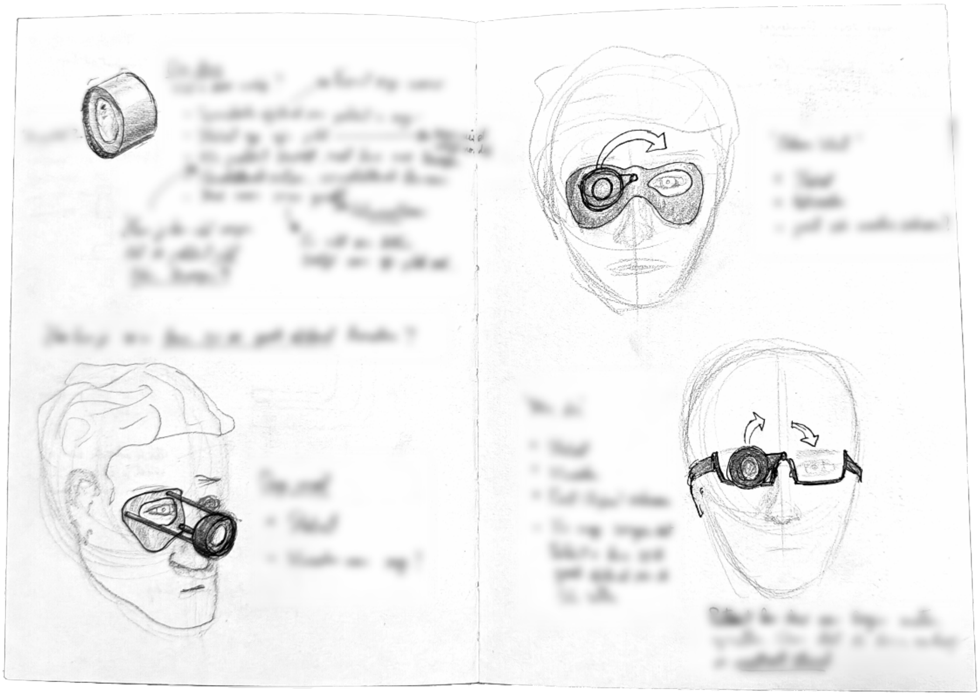


Figure 8-25: Solution idea 2: Lens Glasses

Lens glasses is a solution in Direction D: Attaching retinal lens to Patient. It is a set of glasses worn by the patient, that allows the ophthalmologist to rotate the retinal lens in front of the patient's eye, without having to hold it themselves. This reduces stress on the doctor's arm. Figure 8-25 shows several versions of the idea. The bottom right version is included as it is deemed most practical.

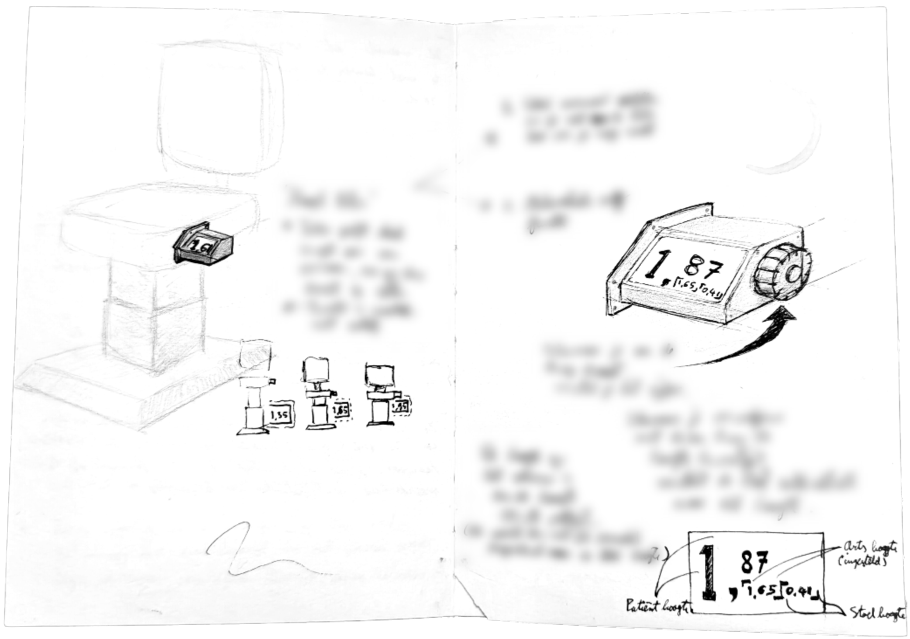


Figure 8-26: Solution idea 3: Reactive/Active meter

Reactive/Active meter is a solution in Direction B: Aligning Doctor and Patient. It is informative and height adjusting addition to the existing patient chair in an ophthalmic outpatient clinic examination room. In Figure 8-26, the initial version on the left, is followed by the improved version to the right. It is this right version that is included in the Harris profile as it provides more functionality. The screen shows the ideal height that a patient should be, when sitting on the chair at the current height, for their eyes to line up with the slit lamp. This number is internally calculated with a formula based on standard person heights and proportions. The number and thus the height of the chair can be adjusted by turning the rotary knob. This increases/decreases the number indicated, until it matches the patient's actual height. This way the chair height can easily be matched to the height of the eyepiece.

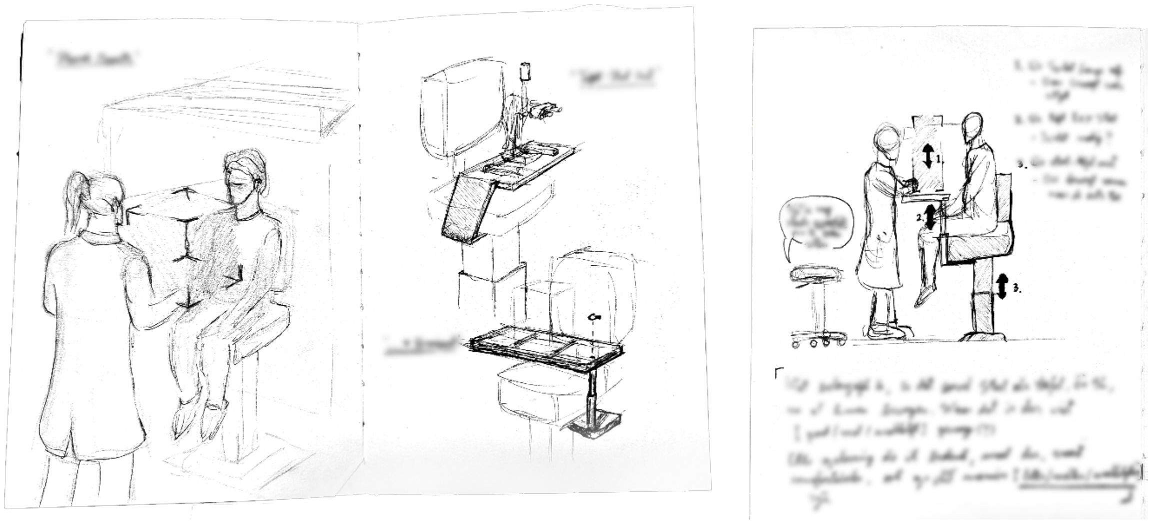


Figure 8-27: Solution idea 4: Standing Doctor

Standing Doctor is a solution in Direction B: Aligning Doctor and Patient. It is a patient chair and slit lamp table combination that allows the ophthalmologist to elevate their full workspace unit proportionally, allowing them to work standing up. As the whole unit moves up and down together, the doctor can transition between standing and sitting seamlessly. Figure 8-27 shows the envisioned working scenario on the left. The middle shows two versions of the table, with the bottom one being chosen as it allows the table to come away from the patient, allowing them to stand back up after the examination. The right shows the 3 degrees of adjustability in the idea, (1) the chair relative to the ground, (2) the table relative to the chair and (3) the slit lamp relative to the table.

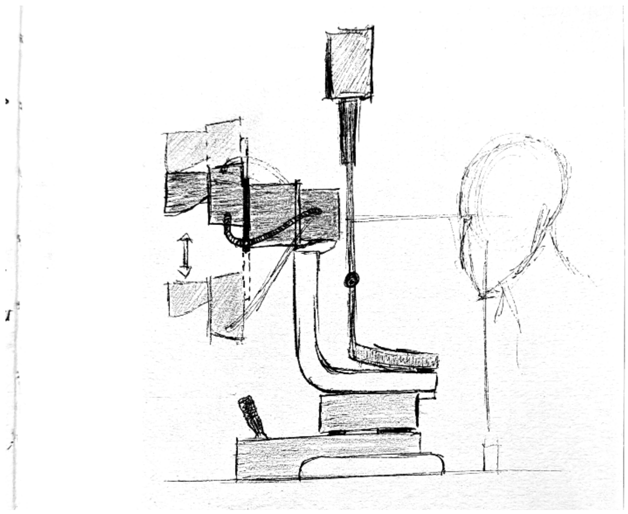


Figure 8-28: Solution idea 5: DigiEyepiece

DigiEyepiece is a solution in Direction A: Redirecting the Picture. It is a partial redesign of the archetypical slit lamp that uncouples the eyepiece from the main body. The non-digital lens based examining equipment is reimagined with a high resolution camera pointed at the patient's eye, as shown in Figure 8-28. The image from this camera is led to the new eyepiece, that now houses a digital screen in it, showing the camera image. By digitizing the image, the eyepiece no longer needs to be in line with the patient's eye, and can instead be positioned by the ophthalmologist in any position comfortable to them.

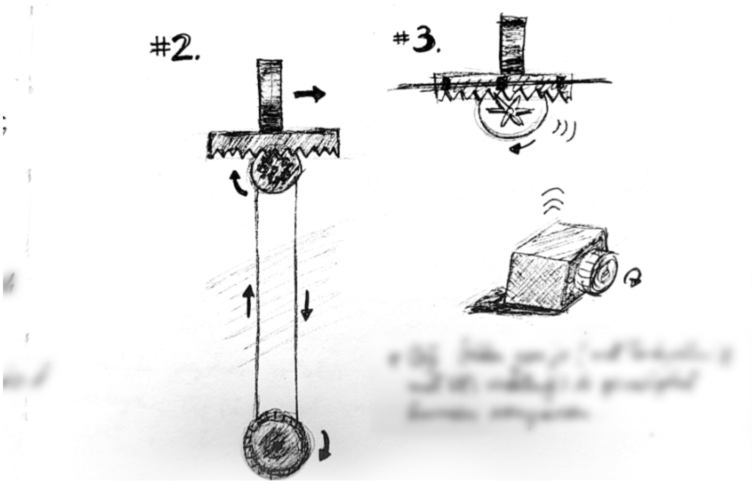


Figure 8-29: Solution idea 6: Lens slider

Lens slider is a solution in Direction C: Attaching Retinal lens to Slit lamp. It attaches the retinal lens to the slit lamp, but instead of being static in place, it is fixed to a slider, allowing it to be manoeuvred back and forth, away from and towards the patient's eye. This is relevant as, as explained in chapter 4.3.4, the distance and position of the lens relative to the patient's eye needs to be very precise, to get a clear image. This is currently done by hand, guided by years of experience, but if the lens were attached, the minute positioning would still need to be facilitated. This solution idea achieves this, as shown in Figure 8-29, by linking the forward position of the lens to a rotating knob. The motion translation is either achieved by gear movements, as seen left in the figure, or by electronic signals and actuators, as seen right in the figure.

Ocu-PC-Cast is a solution in Direction A: Redirecting the Picture. Similar to solution idea 5: DigiEyepiece, a high resolution camera is pointed at the patient's eye, as shown in Figure 8-30, but in this solution, the image from this camera is cast to the ophthalmologist's already present desktop screen. In doing so, the need of a traditional eyepiece on the slit lamp is removed, because of which, poor posture like overreaching or hunching to reach the eyepiece is no longer necessary, nor possible at first place.

To not require the doctor to hold their hand off to the side, to manipulate the traditional lever on the slit lamp, as would be necessary with the configuration in the top of the figure, the lever could also be digitised, allowing the complete ophthalmological work routine, to happen through the desktop.

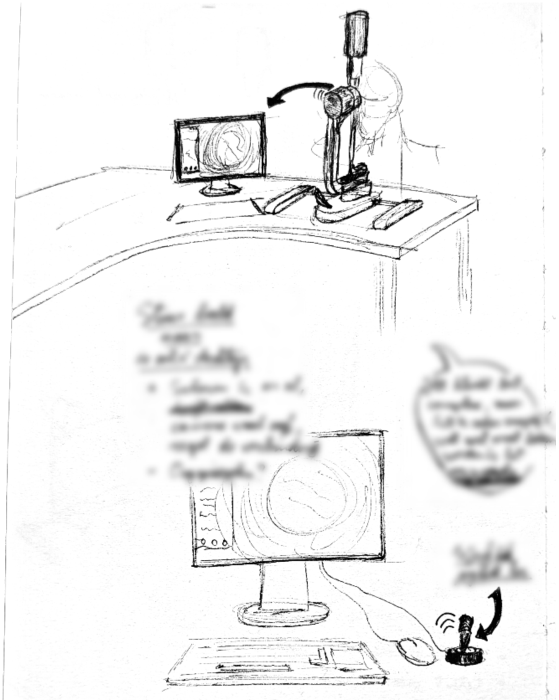
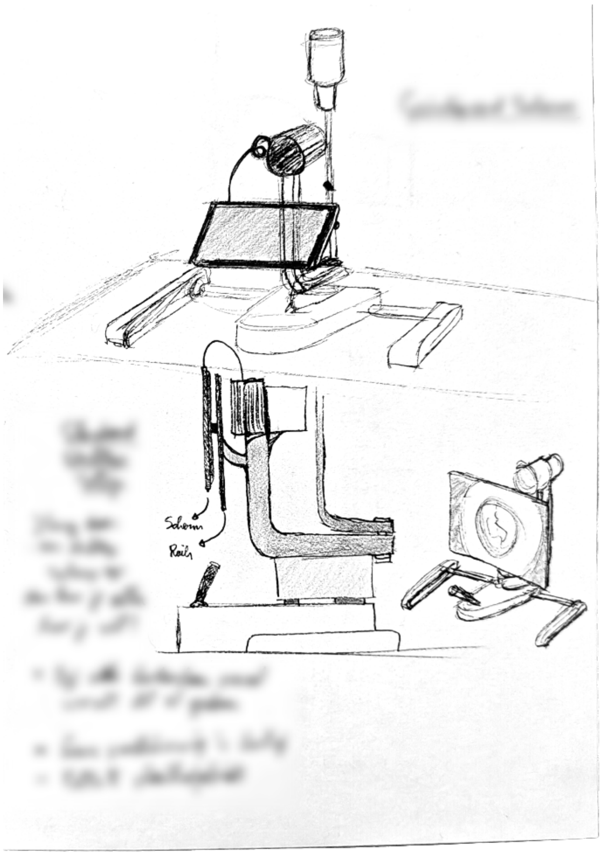


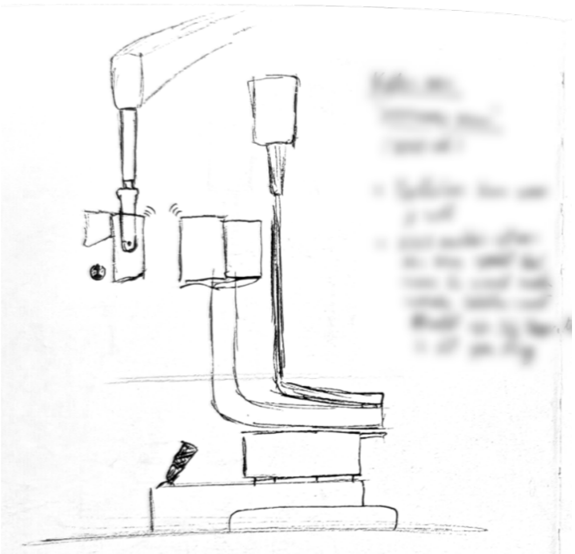
Figure 8-30: Solution idea 7: Ocu-PC-Cast



OcuScreen is a solution in Direction A: Redirecting the Picture. This idea is very similar to the previous, with the main difference that this one places the screen in the very place where normally the eye piece would be. The advantage to this, relative to the Ocu-PC-Cast, is that it is more familiar to the user, as it is closer to the current alternative, which will make adoption easier. It also does not require the Slit Lamp lever to be digitised.

The most important advantage of this idea over the previous however, is that the ophthalmologist is still in a position to use the retinal lens normally. With Ocu-PC-Cast, this would have to be redesigned as well.

Figure 8-31: Solution idea 8: OcuScreen



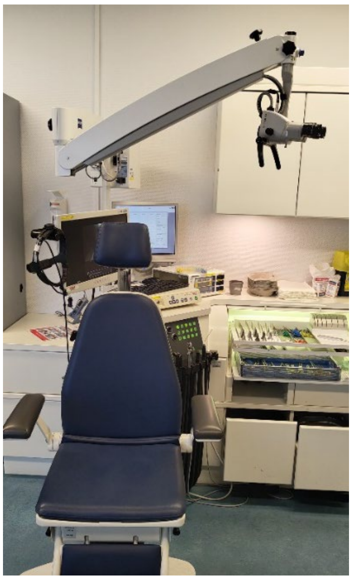


Figure 8-32: (Left) Solution idea 9: Eyepiece arm
Figure 8-33: (Right) ENT doctor's examination equipment

Eyepiece arm is a solution in Direction A: Redirecting the Picture. It is similar to idea 5: DigiEyepiece, in that it is a slit lamp redesign that uncouples the eyepiece from the main body and houses in it a now digital, screen based image, cast from a high resolution camera pointed at the patient's eye.

Different to the other idea however, is that the digital eyepiece is attached to a periscope like arm. This offers the ophthalmologist full flexibility in terms of position in space, if combined with a similarly digitised slit lamp lever. This design is heavily inspired by the scopes that ENT doctors use, as shown in Figure 8-33. For more on ENT doctors, see the glossary at the end of this report.

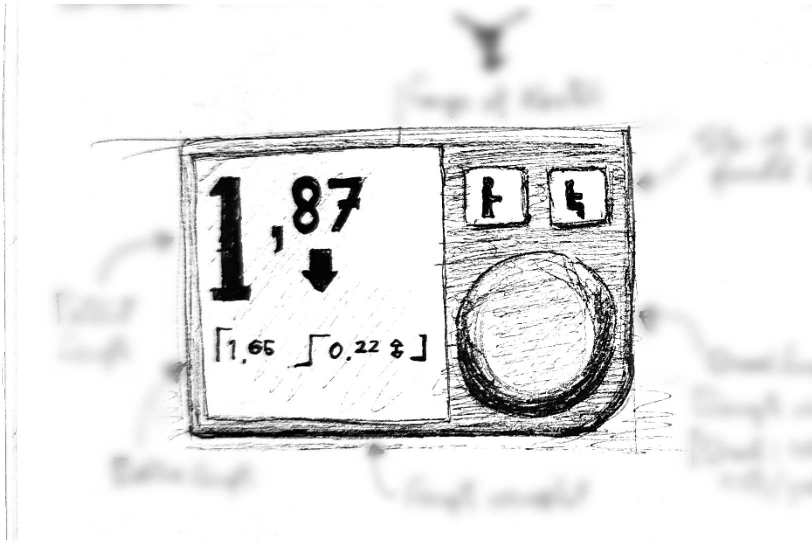


Figure 8-34: Solution idea 10: Height Matcher

Height Matcher is a solution in Direction B: Aligning Doctor and Patient. It is similar to idea 3: Reactive/ Active meter, in that it is a height adjusting addition to the existing equipment, with a screen showing the, formula calculated, ideal height that a patient should be, when sitting on the chair at the current height, for their eyes to line up with the slit lamp. This idea extends this however by also including the ophthalmologist's height. By entering both of these numbers, the product would use formulas based on standard person heights and proportions, to calculate the ideal height for both the patient chair and slit lamp table to be. To optimise ergonomic posture for both ophthalmologist and patient, the product then automatically adjusts the heights of the afore mentioned equipment.

These 10 solutions were assessed using a Harris profile. In this method, a number of solutions are judged based on a set of criteria. They are assigned a score for each criterium on a 4 point scale, -2 being worst, 2 being best. A 0, or neutral score is absent, to force the user to make choices. I took the criteria from the list of requirements in paragraph 4.2, using requirements that are relevant at this level of detail. The criteria used are, Physical ergonomics improvement (1), Patient experience (2), Intuitive use (5.1), Comfortable to use (5.3), Time to use (5.4) and Purchase cost (7).

These criteria are further elaborated on below.

- Physical ergonomics (1)
    - The most important criterium is the improvement of physical ergonomics for the ophthalmologist, this is the goal of the project. Baseline requirement for this criterium is to improve beyond the current situation.
- Patient experience (2)
    - While ergonomics improvement is the goal of the project, this cannot go at the expense of the patient's experience. Baseline requirement for this criterium is to stay equal.
- Use is intuitive (5.1)

    - A badly designed product does not get used, regardless of whether it improves the ergonomics. By making the use scenario intuitive, the concept is more likely to be adopted by the users. The metric used is expected time of instruction, needed to start using the new concept.
- Comfortable to use (5.3)
    - Improving general ergonomics for the ophthalmologist can still decrease the comfort in other activities, or introduce new activities that are uncomfortable in practice, for any party involved. Baseline requirement for this criterium is to stay equal.
- Time to use (5.4)
    - Another criterium to improve the chance of adoption by users is time to use. If it takes longer to use the new concept, when compared to the current alternative, it is unlikely to be adopted, in the fast paced context of ophthalmology. Baseline requirement for this criterium is to stay equal.
- Purchase cost (7)
    - The last criterium concerns medical purchasing. A medical institution is unlikely to purchase the new solution, regardless of ergonomics improvement for its employees, if it costs much more than the current alternative.

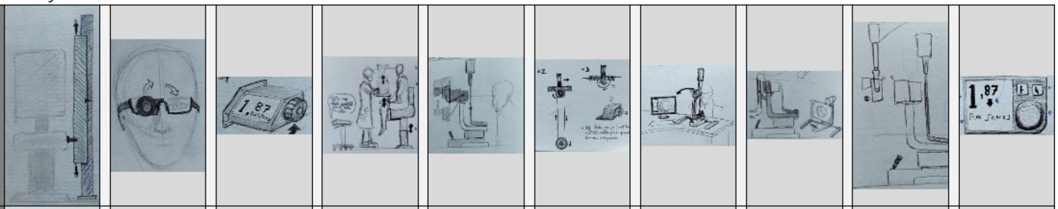
The meaning of the scores in the categories above, are elaborated on in Table 8-22 below.

Table 8-22: Criteria used for Harris profiles and meaning of scores

	-2	-1	1	2
Physical ergonomics	Risk of long term health effects is worse	Risk of long term health effects is equal	Reduces the risk of long term health effects	Reduces the risk of long term health effects (++)
Patient experience	Much worse	Worse	Equal	Better
Use is intuitive	>10 minutes of instructions required	10-2 min	<2min	No instructions required
Comfortable to use	Level of comfort is worse for one or multiple parties (--)	Level of comfort is worse for one or multiple parties	Level of comfort is equal for all parties	Level of comfort is better for one or multiple parties
Time to use	+5 min per patient	+2min	Equal	Quicker
Purchase cost	Purchase cost is higher than replacement cost of current alternative (--)	Purchase cost is higher than replacement cost of current alternative	Purchase cost is comparable to replacement cost of current alternative	Purchase cost is lower than replacement cost of current alternative

The resulting Harris profiles are shown in Table 8-23 below.

Table 8-23: Harris Profiles



	1. Height Slider	2. LensGlasses	3. Reactive-active meter	4. Standing Doctor	5. DigiEyepiece	6. Lens Slider	7. OcuPC-Cast	8. OcuScreen	9. Eyepiece Arm	10. Height Matcher
Physical ergonomics	1	1	2	2	1	1	1	1	-1	2
Patient experience	1	-2	1	1	1	1	1	-2	1	1
Use is intuitive	2	2	1	1	2	2	1	1	1	1
Comfortable to use	-2	-1	1	2	1	1	-1	-1	-1	2
Time to use	-1	2	-1	-1	1	-1	1	1	-1	1
Purchase cost	2	2	-1	-2	-1	-1	-1	-1	-1	-2

When determining the results of the Harris profiles, idea 10: Height Matcher is the clear winner. It strongly reduces the risk of long term health effects and has a high comfort of use. It furthermore scores positive on all other categories. Purchase cost is the only negative, as the concept would be a full replacement of the examination unit, except for the slit lamp. Even though the high purchase cost is something to keep in mind for future development, it is likely to be comparable to the replacement cost for to the current, existing unit.

Appendix 15 : Initial concept

This appendix describes height matcher as it was initially conceptualised, in its earlier form.

I initially envisioned height matcher to be automated by means formulas. The concept would consist of much the same physical parts as described in the final concept, but instead of manually adjusting the parameters, these would be automatically driven.

The input would be patient height and the ophthalmologist's height and as a result, this formula I developed (Figure 8-35, below), would output the appropriate distance from ground to patient chair (C, in Figure 8-36, below) and patient chair to slit lamp table (T). Combining these motorised measurements with the height of the slit lamp being used (E+OP) this would result in the perfect eyepiece height for the doctor (D) and by means of electromotor powered table and chair, both patient and doctor would sit in a comfortable, ergonomical posture.

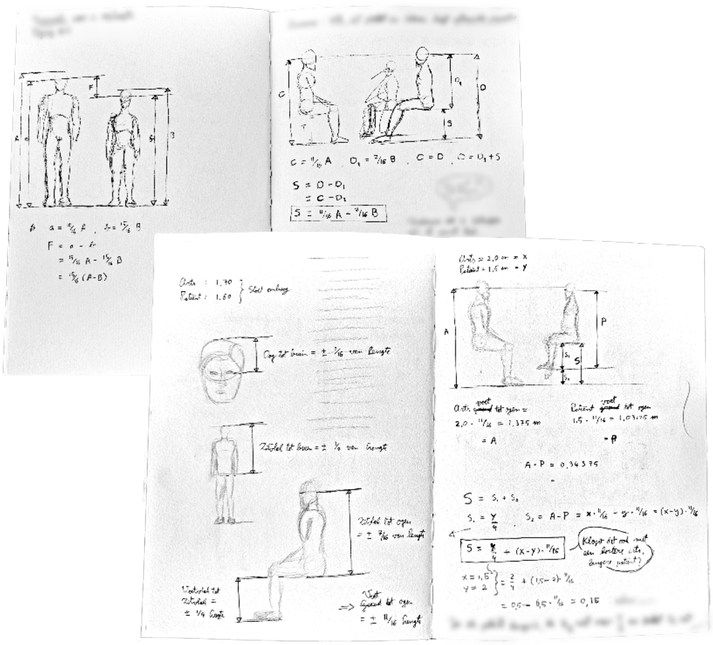


Figure 8-35: Making the Formula

The list of leading and resulting measurements is as follows:

- Ophthalmologist height = A
- Patient height = B
- Patient seat height = C
- Seat to patient eye height = P
- Seat to table top = T
- Table top to patient eye height = E
- Patient eye height to eyepiece height = OP
- Eyepiece height from floor = D

The formulas are as follows:

Seat to table top : $T = \frac{7}{16}B - E$

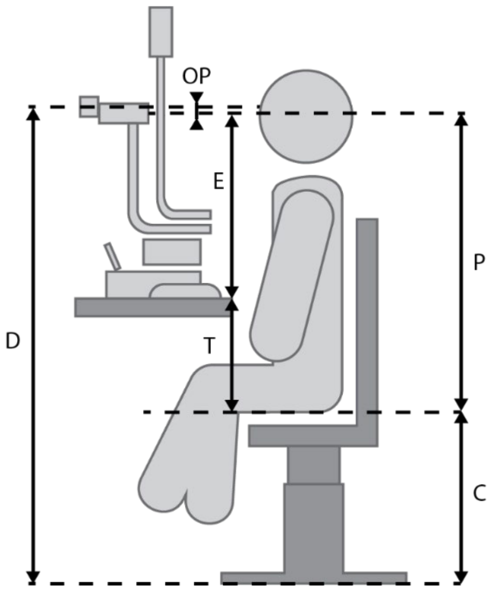


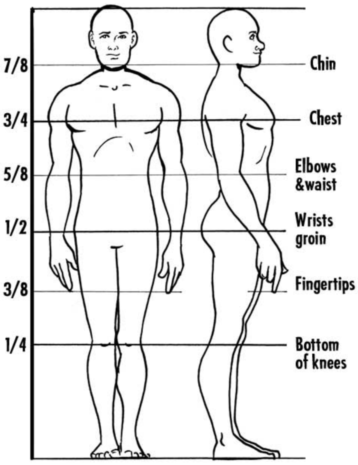
Figure 8-36: Schematic representation of relevant measurements in examination equipment

Patient seat height (Doctor sitting) :

$$C = \frac{11}{16}A - \frac{7}{16}B - AP$$

Patient seat height (Doctor standing) :

$$C = \frac{15}{16}A - \frac{7}{16}B - AP$$



These theorised formulas are based on generalised human proportions as shown in Figure 8-37.

To assess the validity of the formulas, the anatomical TU Delft database, DINED, was consulted. I compared the theorised ratio's between eye height and full height (15/16), with the measured data from DINED for the population of 20 and 30 years old, 31 and 60 years old, and over 60 years old, all genders.

These comparisons are shown in the tables below.

Figure 8-37: Theoretical human proportions

Table 8-24: Theory compared to DINED database, dataset Dutch adults, 60+ years old, m+f

Data set (Patients)								
Dutch Adults, dined 2004								
Age bracket								
60+ m+f								
	Percentile	**Stature**	**Eye height, standing**	**Stature/Eye height**	**Absolute difference**		**% difference**	
		floor to crown [mm]	floor to eyes [mm]		Measurent - expectation [mm]		Absolute difference / Stature * 100	
	Expectation	*16*	*15*	*0,937500*	*0,000000*	*mm*	*0,000000*	*%*
	0.01	1356	1259	*0,928466*	-0,009034	mm	-0,000666	%
	10	*1594*	*1493*	*0,936637*	-0,000863	mm	-0,000054	%
	15	1616	1514	*0,936881*	-0,000619	mm	-0,000038	%
	20	1633	1531	*0,937538*	0,000038	mm	0,000002	%
	25	1648	1545	*0,937500*	0,000000	mm	0,000000	%
	30	1662	1557	*0,936823*	-0,000677	mm	-0,000041	%
	35	1674	1569	*0,937276*	-0,000224	mm	-0,000013	%
	40	1685	1580	*0,937685*	0,000185	mm	0,000011	%
	45	1696	1591	*0,938090*	0,000590	mm	0,000035	%
	50	1708	1602	*0,937939*	0,000439	mm	0,000026	%
	55	1719	1613	*0,938336*	0,000836	mm	0,000049	%
	60	1731	1624	*0,938186*	0,000686	mm	0,000040	%
	65	1743	1635	*0,938038*	0,000538	mm	0,000031	%
	70	1755	1647	*0,938462*	0,000962	mm	0,000055	%
	75	1768	1659	*0,938348*	0,000848	mm	0,000048	%
	80	1783	1674	*0,938867*	0,001367	mm	0,000077	%
	85	1800	1690	*0,938889*	0,001389	mm	0,000077	%
	90	1822	1711	*0,939078*	0,001578	mm	0,000087	%
	99.99	2039	1918	*0,940657*	0,003157	mm	0,000155	%
	Average			0,937916	0,000063	mm	-0,000006	%

Table 8-25: Theory compared to DINED database, dataset Dutch adults, 20-30 years old, m+f

Data set						
Dutch Adults, dined 2004						
Age bracket						
20-30 m+f						
	Percentile	**Stature**	**Eye height, standing**	**Stature/Eye height**	**Absolute difference**	**% difference**
		floor to crown [mm]	floor to eyes [mm]		Measurent - expectation [mm]	Absolute difference / Stature * 100
	Expectation	*16*	*15*	*0,937500*	*0,000000 mm*	*0,000000 %*
	0.01	1377	1286	*0,933914*	-0,003586 mm	-0,000260 %
	10	*1621*	*1514*	*0,933991*	-0,003509 mm	-0,000216 %
	15	1648	1540	*0,934466*	-0,003034 mm	-0,000184 %
	20	1669	1561	*0,935291*	-0,002209 mm	-0,000132 %
	25	1687	1578	*0,935388*	-0,002112 mm	-0,000125 %
	30	1704	1594	*0,935446*	-0,002054 mm	-0,000121 %
	35	1719	1609	*0,936009*	-0,001491 mm	-0,000087 %
	40	1733	1622	*0,935949*	-0,001551 mm	-0,000089 %
	45	1747	1636	*0,936463*	-0,001037 mm	-0,000059 %
	50	1761	1649	*0,936400*	-0,001100 mm	-0,000062 %
	55	1775	1662	*0,936338*	-0,001162 mm	-0,000065 %
	60	1789	1676	*0,936836*	-0,000664 mm	-0,000037 %
	65	1803	1689	*0,936772*	-0,000728 mm	-0,000040 %
	70	1818	1704	*0,937294*	-0,000206 mm	-0,000011 %
	75	1835	1720	*0,937330*	-0,000170 mm	-0,000009 %
	80	1853	1737	*0,937399*	-0,000101 mm	-0,000005 %
	85	1874	1758	*0,938100*	0,000600 mm	0,000032 %
	90	1901	1784	*0,938453*	0,000953 mm	0,000050 %
	99.99	2166	2040	*0,941828*	0,004328 mm	0,000200 %
	Average			0,936349	-0,000991 mm	-0,000064 %

Table 8-26: Theory compared to DINED database, dataset Dutch adults, 31-60 years old, m+f

Data set						
Dutch Adults, dined 2004						
Age bracket						
31–60 m+f						
	Percentile	**Stature**	**Eye height, standing**	**Stature/Eye height**	**Absolute difference**	**% difference**
		floor to crown [mm]	floor to eyes [mm]		Measurent - expectation [mm]	Absolute difference / Stature * 100
	Expectation	*16*	*15*	*0,937500*	*0,000000 mm*	*0,000000 %*
	0.01	1377	1286	*0,933914*	-0,003586 mm	-0,000260 %
	10	*1594*	*1493*	*0,936637*	-0,000863 mm	-0,000054 %
	15	1616	1514	*0,936881*	-0,000619 mm	-0,000038 %
	20	1633	1530	*0,936926*	-0,000574 mm	-0,000035 %
	25	1648	1545	*0,937500*	0,000000 mm	0,000000 %
	30	1661	1557	*0,937387*	-0,000113 mm	-0,000007 %
	35	1674	1569	*0,937276*	-0,000224 mm	-0,000013 %
	40	1685	1580	*0,937685*	0,000185 mm	0,000011 %
	45	1697	1591	*0,937537*	0,000037 mm	0,000002 %
	50	1708	1602	*0,937939*	0,000439 mm	0,000026 %
	55	1719	1613	*0,938336*	0,000836 mm	0,000049 %
	60	1731	1624	*0,938186*	0,000686 mm	0,000040 %
	65	1742	1635	*0,938576*	0,001076 mm	0,000062 %
	70	1755	1647	*0,938462*	0,000962 mm	0,000055 %
	75	1768	1659	*0,938348*	0,000848 mm	0,000048 %
	80	1783	1674	*0,938867*	0,001367 mm	0,000077 %
	85	1800	1690	*0,938889*	0,001389 mm	0,000077 %
	90	1822	1711	*0,939078*	0,001578 mm	0,000087 %
	99.99	2039	1918	*0,940657*	0,003157 mm	0,000155 %
	Average			0,937912	0,000346 mm	0,000015 %

Drawing from these one dimensional data, as shown in the tables above, the resulting difference between the theory and the measured data, as a percentage of full stature is less than 0,1%.

This confirmation posed a promising direction for ophthalmologists' ergonomics improvement, however, when consulting the more detailed ellipse analysis data in the same database, the difference between fact and theory becomes much larger. In the ellipse analysis comparing Stature to Eye Height in the figure below, numbered points represent the theory. The ellipse represents spread of true measurements.

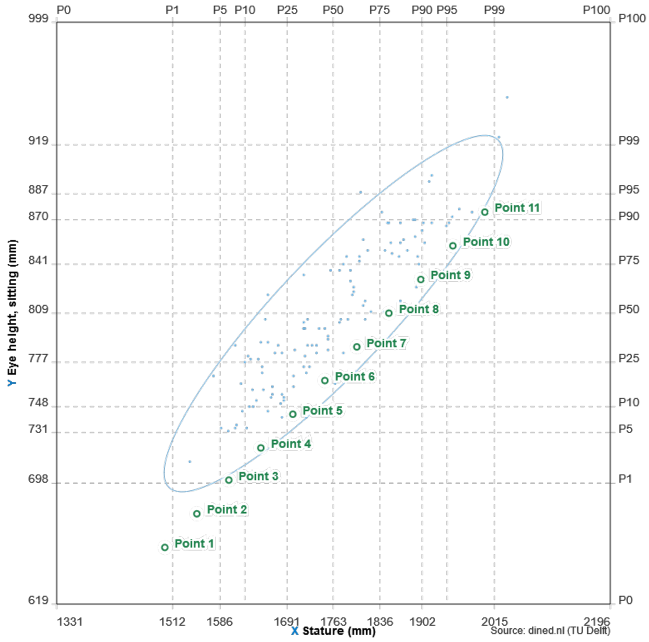


Figure 8-38: Ellipse analysis comparing Stature to Eye Height.
Numbered points represent theory, ellipse represents spread of true measurements

The difference and variance thus becomes so large, that even with an adjustment, the validity of the formula falls apart. For this reason, I moved away from formula based adjustment and towards the manually controlled, extended adjustment that is described in the main body of this report.

Appendix 16 : Measuring stick design stages

In this appendix, I will explain the design process that led to the final measuring stick design.

Figure 8-39 below shows the early sketches for the concept measuring stick.

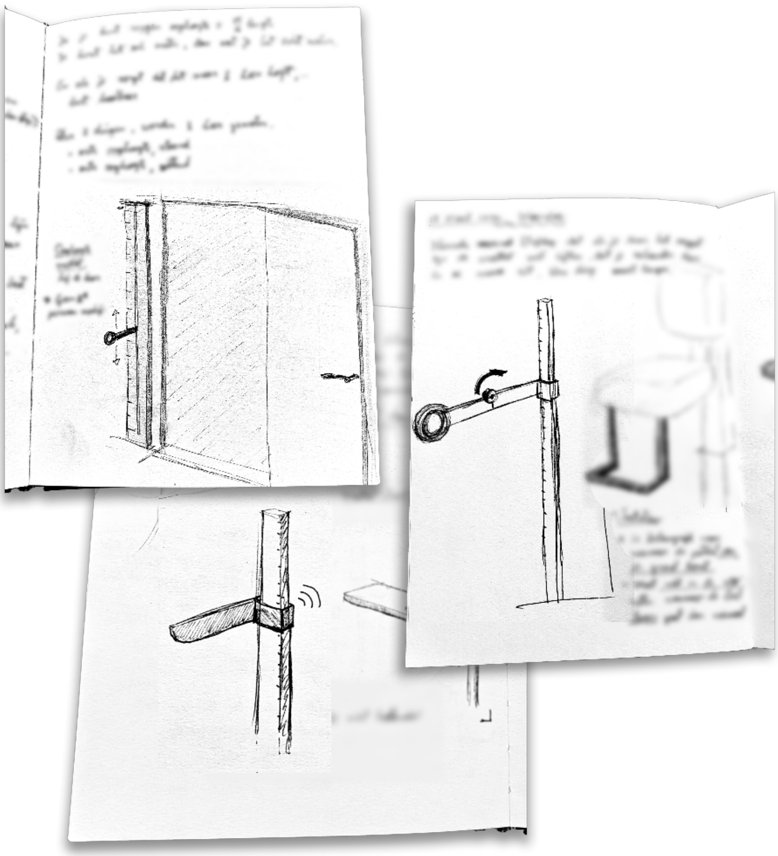


Figure 8-39: Early sketches for measuring stick

The bottom sketch shows one of the first, most basic iterations of the measuring stick concept.

As shown in the sketch on the left, an idea that surfaced early on, was to place the measuring stick next to the door, inside the clinic room. This would be to facilitate the interaction of measuring the eye height, as the doctor comes into the room. This was later changed to a single measurement being done at the beginning of the doctor's career

The sketch on the right shows the first exploration into making the slider arm extendable. An aspect necessary to make the extending piece long enough for the ophthalmologist to stand with shoulder to the wall during the measurement. This idea came about through the conclusions from the user tests.

Figure 8-40 below shows the various stages of the concept measuring stick throughout the design process.

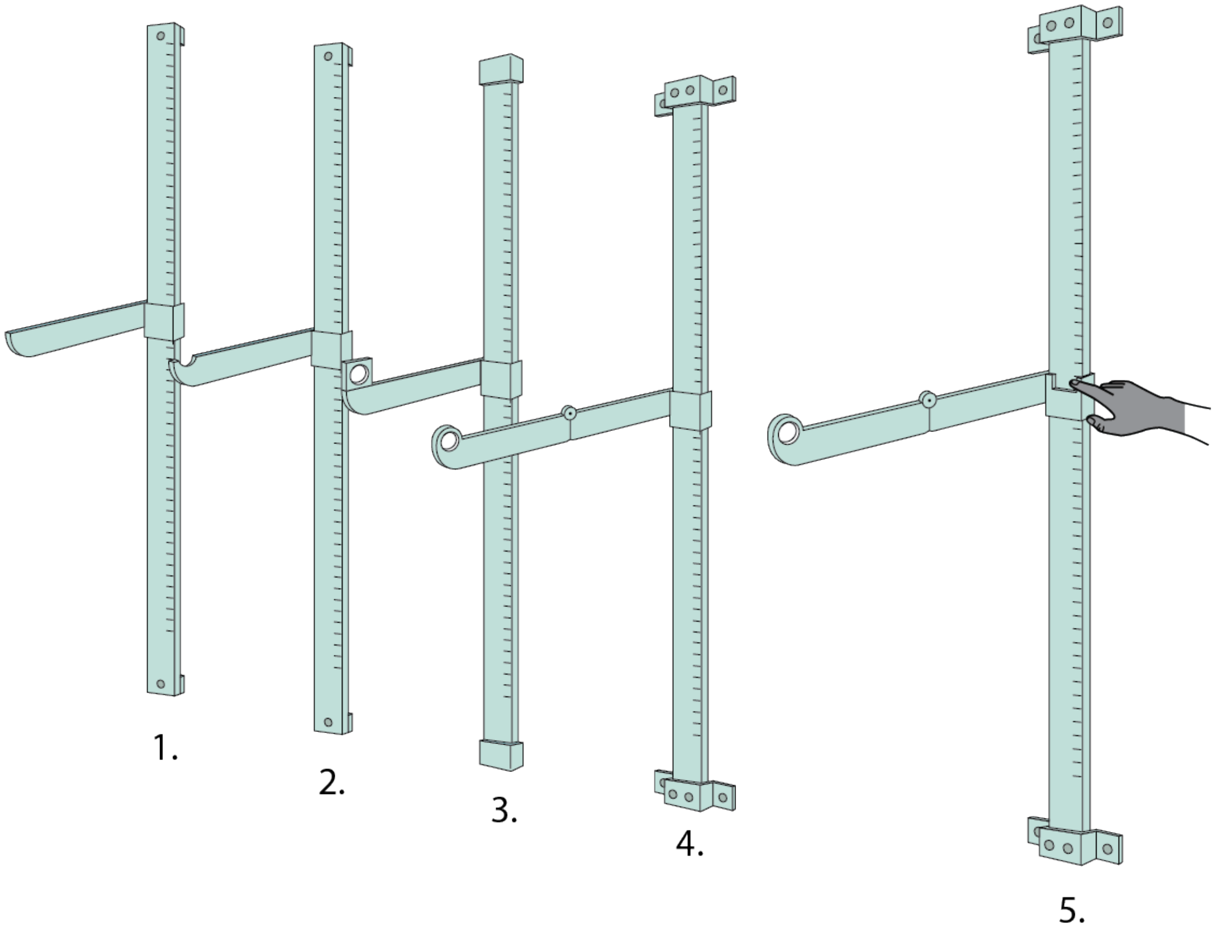


Figure 8-40: The concept measuring stick at different stages of the design process

1. The initial design shown on the very left, was devised as the simplest version of the idea. That is, a long beam with printed measurements, affixed to the wall on either end, with a slider that allows the user to take their eye height measurement by reading the corresponding metric on the beam.

2&3. Through the iterations, construction and ease-of-use was improved. Among others, an eye hole was added to remove ambiguity from the measurement.

4. In this iteration the aforementioned extendable slider arm was added.

5. I additionally iterated more on the main slider body, with cutouts to make reading the measurement easier.

The figure below shows the latest iteration, including a locking pin that falls into the beam ridges to support the slider in place. This pin is lifted when the slider is moved and falls back down after.

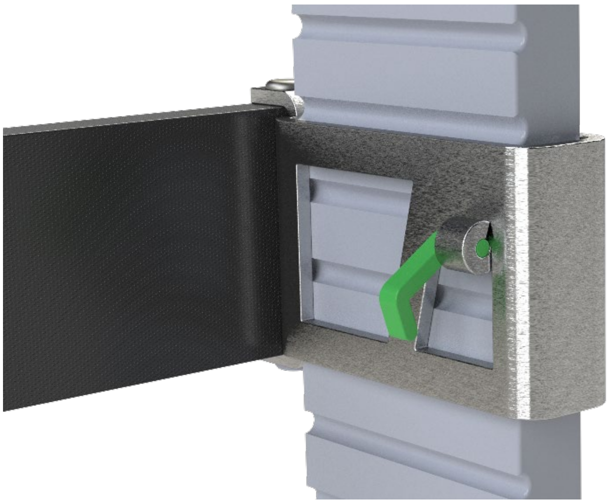


Figure 8-41: Latest slider iteration including locking pin (in green)

As shown in Figure 8-42 below by the red line, the bottom of the reading window is exactly in line with the middle of the eye hole. This further removes ambiguity in the measurement, to make sure that the measurement is sound.

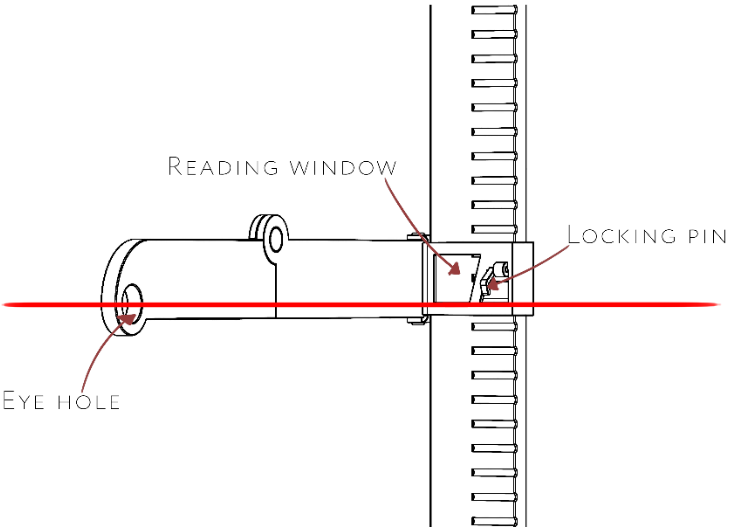


Figure 8-42: The Eye hole is exactly in line with the bottom of the reading window

The next appendix will go into the development of the next part of the concept, the chair/table unit.

Appendix 17 : Chair/table unit design stages

In this appendix, I will explain the design process that led to the final chair/table unit design.

Figure 8-43: Current chair/table unit

The current alternative commonly looks like the unit shown in Figure 8-43. A patient chair, with or without arm rests, that can be adjusted in depth and height over a range of around 20 cm.

Separate to this is a slit lamp table unit, sometimes connected to a larger desk, that slides the whole table top with slit lamp in front of the patient, allowing the ophthalmologist to examine them. Often the table can also slide out further yet, to give access to secondary examination equipment

The table is controlled with a hand panel, generally affixed to the desk, while the chair is either controlled by a hand panel, or a foot pedal.

Appendix 17.1 : First concept

The conceptualised standing mode, in which an ophthalmologist can do the full patient examination while standing up, requires for the relative distance between the slit lamp table and patient chair to stay constant while raising from sitting to standing mode, and back down. The initial chosen solution for this was to connect the table and chair, instead of having them as separate machines, as is the case currently. The table was placed on a swivel arm, connected to the bottom of the chair, as shown in Figure 8-44. This is already done in some uncommon existing alternatives, as shown in Figure 8-45.

The current consensus on these existing alternatives, is suboptimal ergonomics as they are rather strenuous to use. The table uses a magnet lock to keep the table in place. To move it, the doctor presses a button to disengage the magnet, after which the table is brought in position manually. This is unassisted and rather laborious, due to the weight of the table. The functional swing element of the table was therefore used, but the strenuous movement thereof was improved upon by replacing it with motorised rotation.

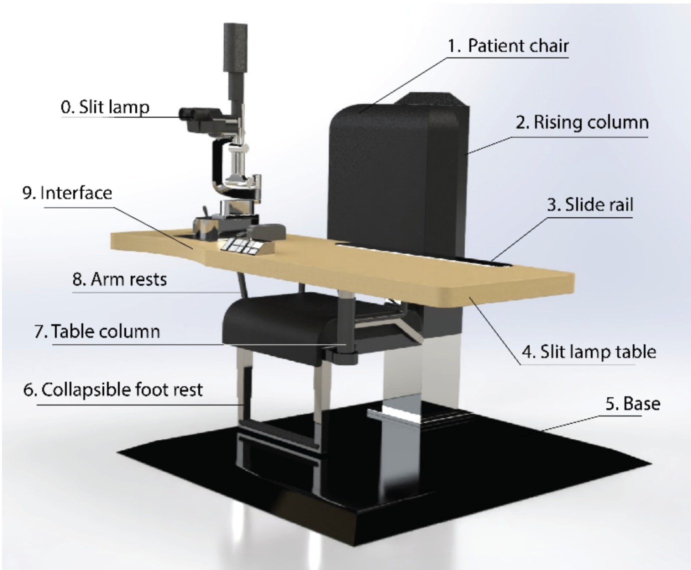


Figure 8-44: The adapted Chair/Table Unit, parts

In this concept design, all parts are affixed to the posterior rising column. What this achieves, is stability. As all parts are moved by the same actuator in the column, relative chair to table distance always stays equal, regardless of the height at which the unit is set by the ophthalmologist. This begets seamless height transition, and speeds up the interaction.

Figure 8-45: Existing slit lamp table with moving swivel arm

It was for several reasons however, that I later moved away from the direct table to chair connection.

1. **Material strength**. In this design, the weight of the entire unit, that being, the chair, table, equipment, as well as the patient, is carried by the same posterior column. This would require considerable engineering to safely and reliably realise, and while, with the proper materials, dimensions, and actuators, it is fully possible to realise, it is unnecessary because of the second reason.
2. The reason to affix the two, is **movement practicality**. Maintaining table to chair distance is easy when they are connected, but the way in which they are interacted with makes the connection impractical. The proposed interaction (chapter 3.a), has the ophthalmologist adjust the table once per day, and adjust the chair to most every patient. With the table-to-chair connection, this would mean that, every time the chair is moved up (green arrow in Figure 8-46), the table would have to come down (red arrow in figure), to maintain the same table height for the doctor (green dotted line in figure).

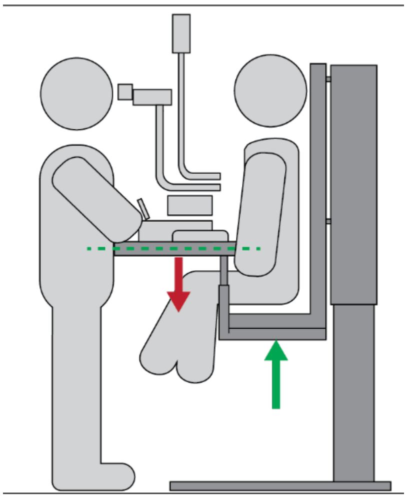


Figure 8-46: Movement Impracticality

Appendix 17.2 : Iteration: Table column

The way to more easily maintain the same table height for the doctor, is by giving the table its own rising column, as shown in

Figure 8-47. By sufficiently calibrating the two actuators in chair (1) and table (2), relative distance can still be maintained.

Figure 8-47: Separate table rising column

After this iteration, several problems remain that need to be attended to.

1. The thick base plate poses a tripping hazard for patients getting onto the chair. This is intensified by the fact that the typical patient demographic consists of elderly people, with limited mobility.
2. In moving the patient chair forward, the hand rails could collide with the table.

The baseplate cutout, shown in the figure on the right removes the tripping hazard for patient getting into the chair.

The problem where the hand rails could collide with the table when moving the patient chair forward is solved by making the rails low enough to fit under the table. Furthermore, the stills in Figure 8-84 below show their new function to pivot backwards to facilitate more corpulent patients, that would otherwise not fit between them.

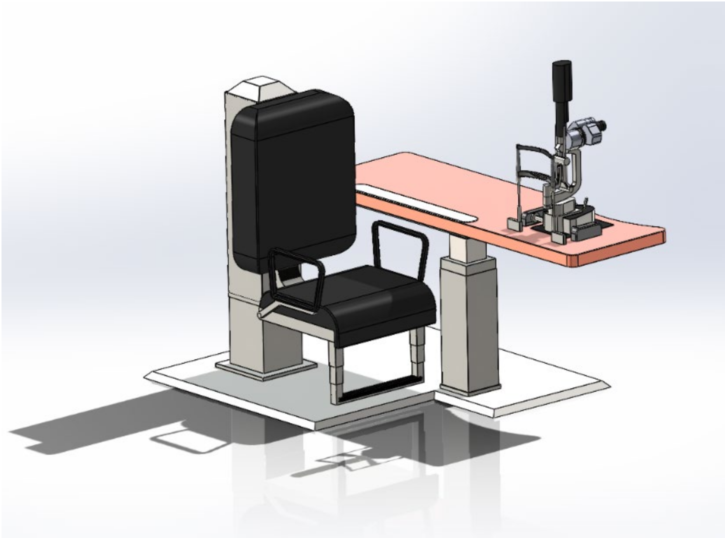


Figure 8-48: Baseplate cut out to prevent tripping

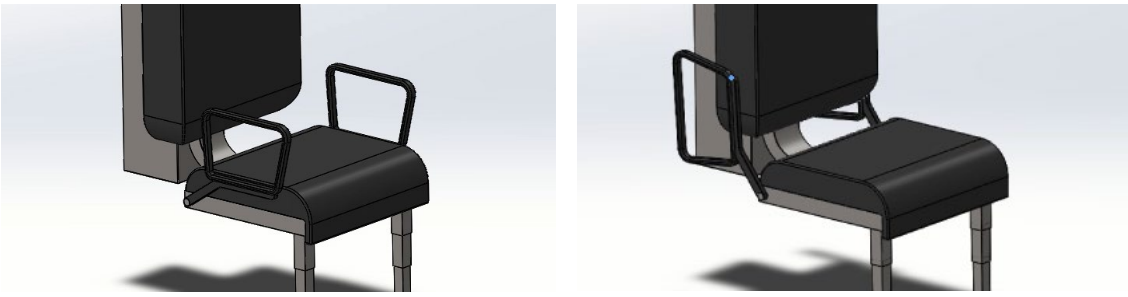


Figure 8-49: Chair armrests movements to accommodate more corpulent patients

Appendix 17.3 Iteration: Feasibility

At this point in the design process, I took a closer look at the unit design in terms of construction. The base of the version as it is shown above is, in essence, a base plate with two columns on it. To make the construction more realistic, I analysed existing alternatives .

			
Topcon IS-1 unit (Medical Workshop, n.d.-b)	Haag-Streit Doms HS-810 (Laméris, 2024)	BLOCK IDEO (Laser vision, 2024)	Topcon IS-600 III unit (Medical Workshop, n.d.-c)

Figure 8-50: Existing alternatives of swivel table units

The design guidelines I took away from these are as follows:

- The table rising column is always supported by a larger supporting body, connected directly to the base plate. This is likely to increase structural integrity, as the table is entirely supported by the axis. This body is an important addition for the construction, to guarantee stability.
- Swivel table units have a shorter table top than tables with linear movement. This can be explained by the different supporting structure. On linear tables, the table is supported more, while with swivel tables, the whole weight is supported by the axis. The table top on swivel tables units is therefore smaller and shorter to decrease the force that is put onto the axis.

The next concept iteration, including the design guidelines outlined above, is shown below.

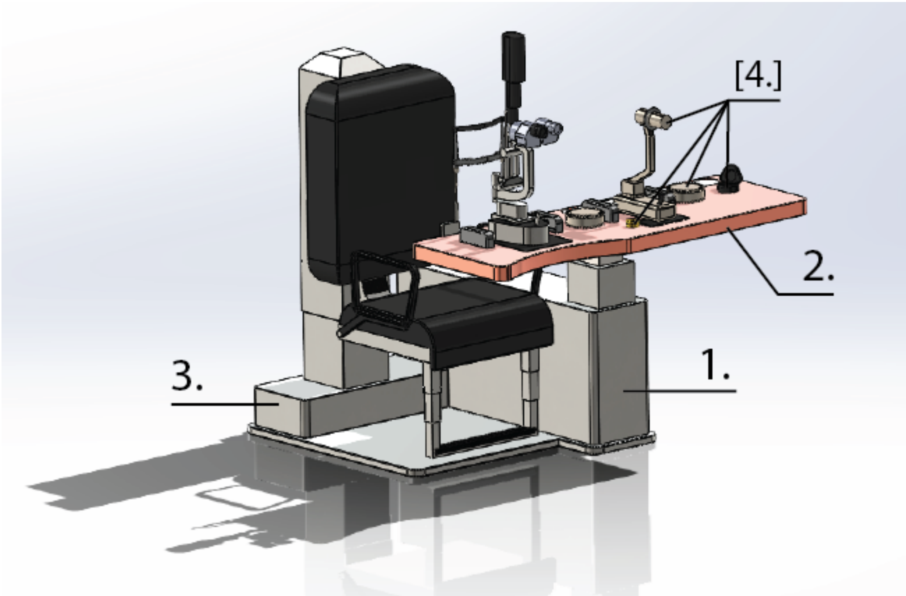


Figure 8-51: Iteration with improved constructive elements

Several design changes shown above are:

1. A structural supporting body was added around the table axis
2. The table is shortened to reduce forces on the axis
3. A structural supporting body was added around the posterior column
4. [secondary examination equipment, elbow pads and retinal lens + lens case were added to the model to better visually illustrate the context]

To further confirm the feasibility of the design, I conducted an interview with a representative of a large medical supplier. This interview is included in Appendix 8Appendix 22 :. The main takeaways from this interview in terms of the table unit design were as follows:

- The base plate of the table and the base plate of the chair should either be entirely separate, or separable. In the first case this means the two would be distinct, and disconnected units. In the second case the two are separate until installation, at which point they are connected. The reasons for this are, firstly, practicality as a unit with the two connected would hardly fit through a door; and secondly occupational safety during installation, as such a connected unit would be so heavy as to be dangerous for the technicians installing it.
- The best place for the interface to be installed, is on a stationary body under the moveable table, to the right of the ophthalmologist.
- Swivel table units, as well as units with any other movement types (linear, circular or two-point arm, see 0 Appendix 7.2: Table unit), always have a phoropter pole. This pole is specifically

included to attach a phoropter, an apparatus used to measure a patient's prescription for corrective lenses. This is an important feature that needs to be included.

- The table should be shortened to decrease the force carried by the axis.

The split baseplate was immediately implemented as shown below. The two parts slot into each other during installation and are bolted for semi-permanent connection. This slot also contains connectors to connect the unit sections electronically.

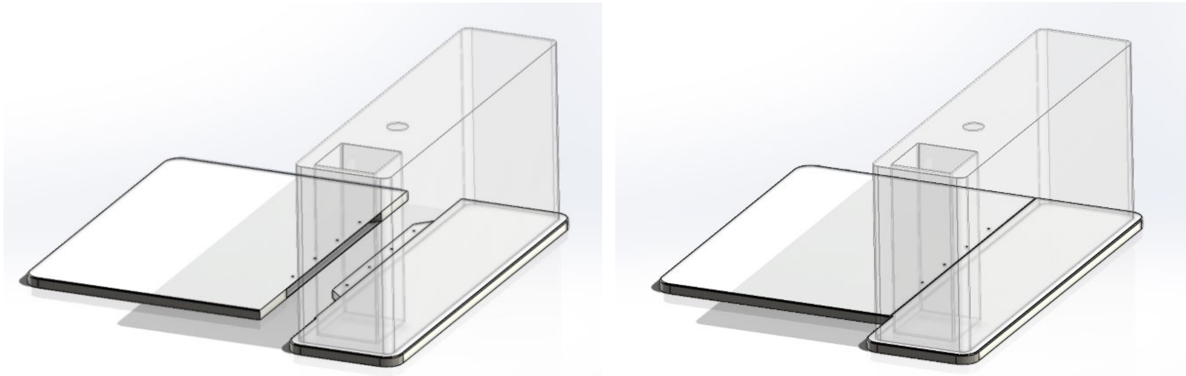


Figure 8-52: Baseplate split to ease transport, connected during installation for overall rigidity

The phoropter pole was additionally included henceforth. The design step influenced by the fourth interview conclusion, on the best place for the interface, is elaborated on next.

Appendix 17.4 : Iteration: Interface body

Concluding from the industry representative interview, it is best to install the interface on a stationary body under the table, to the right of the ophthalmologist. This paragraph elaborates on how this was realised in the design.

Several options were considered.

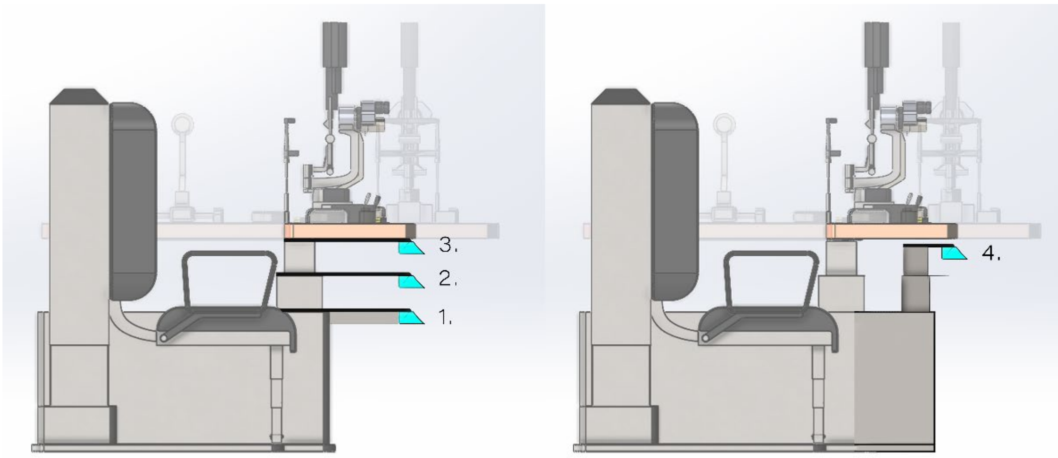


Figure 8-53: Attachment options for interface under table

Option 1 from the figure above, and shown 3D modelled below left, has the interface connected to the table's supporting body. An advantage of this option is that its construction is simple to construct and implement, which is likely why existing alternatives already employ it. It however does not work for the purpose of this concept as, in standing mode, the interface would be too low, at 46cm off the ground, or around the doctor's knee height.

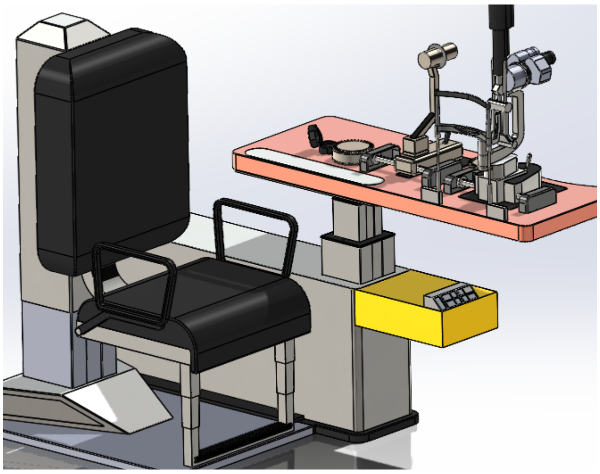


Figure 8-55: Option 1: Extra body on table supporting body

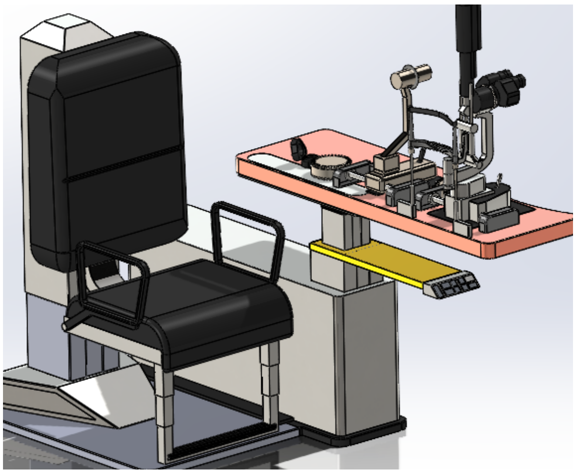


Figure 8-54: Option 2: Extra body on mid part table pillar

Option 2, above right, has the interface connected to the middle of the table's pillar. An advantage of this option is that the interface is at a more appropriate height for the doctor in most of the table's range of motion, with the exception of the high end, where the distance becomes greater.

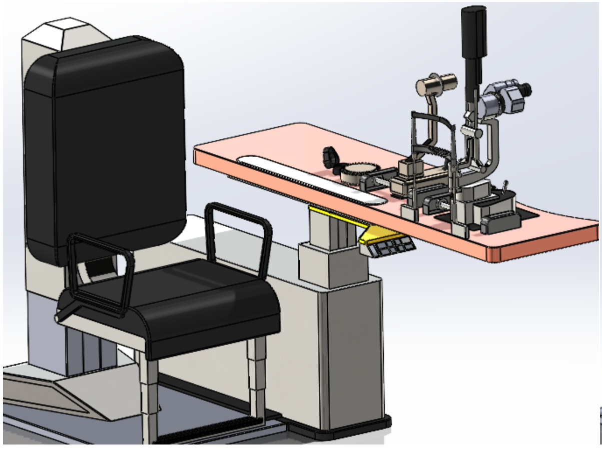


Figure 8-57: Option 3: Extra body on top part table pillar

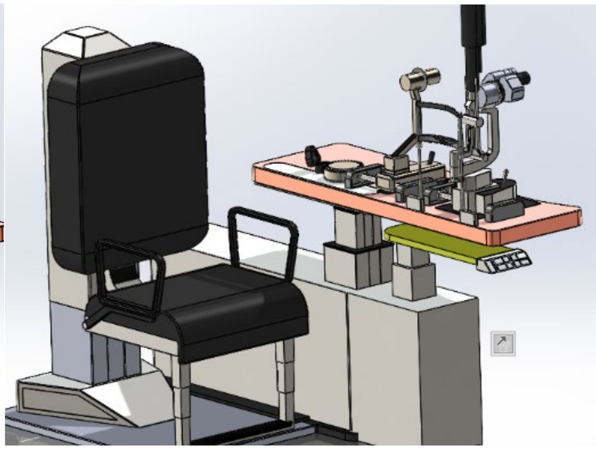


Figure 8-56: Option 2: Extra body on top part table pillar

Option 3, above left, has the interface connected to the top of the table's pillar, directly under the table. An advantage of this option is that the height of the interface is always constant, relative to the table, regardless of its movement. This apparent best option does however lead to a safety hazard, where upon swivelling the table, the doctor could get their fingers between the interface body and the table.

Option 4, above right, has the interface connected to a separate pillar, that moves up and down proportionally to the table. An advantage of this option is that the interface can be at the perfect height at all times. The significant disadvantage is that it comes at the cost of increased complexity.

Figure 8-58: Comparison of interface body options

	Interface position in sitting mode	Interface position in standing mode	Other disadvantages
Option 1: On table support	Good	Poor	-
Option 2: Mid table pillar	Good	Suboptimal	-
Option 3: Top table pillar	Good	Good	Safety hazard
Option 4: Separate pillar	Good	Good	Increased complexity

When considering these options in terms of interface position, relative to the doctor and the movement of the table, option 3 and 4 are the best options. Option 4's increased complexity is an inherent part of the option, while the safety hazard in option 3 can be alleviated by an adjusted design. For this reason, option 3 is chosen to go forward with.

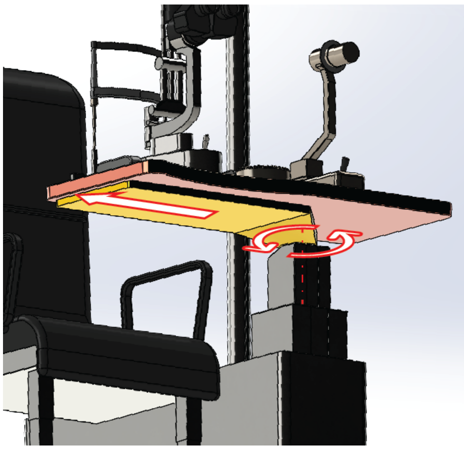


Figure 8-59: Underside table, new part in yellow

Appendix 17.5 : Iteration: Shortening table

The next iteration focussed on the table movement, for which reason the table was split into two parts with their own functionality.

The movement functionality of the table, apart from up and down, consists of rotation and sideways translation. These functionalities are embodied in the part indicated in yellow in the left figure. The part connect to the pillar axis on one side, and provides a rail for the table to slide out. This facilitates the use of the secondary equipment.

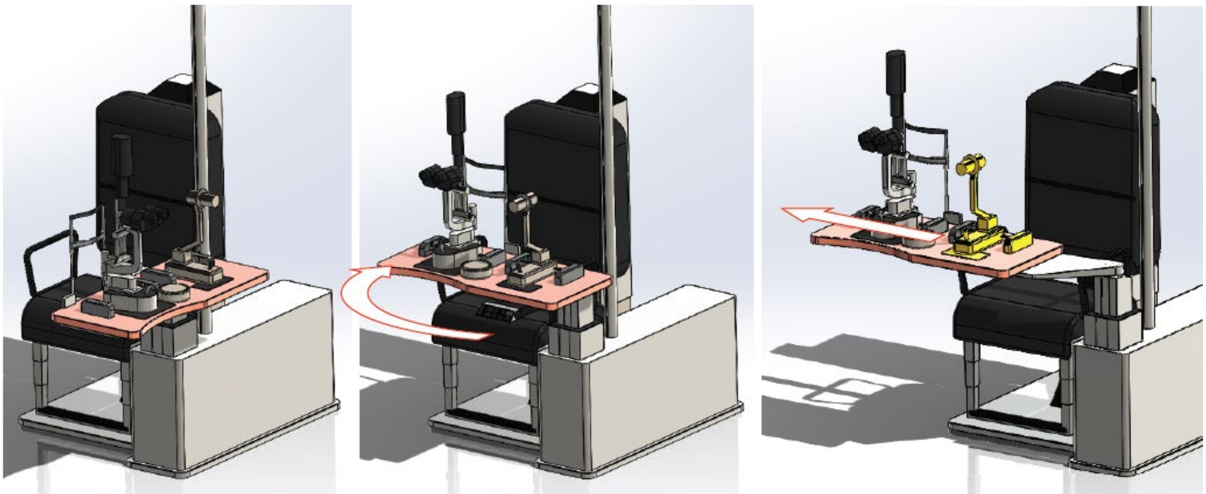


Figure 8-60: Table movement for engaging secondary equipment

The resulting movement, for engaging the secondary equipment (yellow) is shown in the figure above. This component layout with rotation and translation split this way is inspired by existing alternatives. Where the concept differs from these is that existing alternatives do not provide motorised rotation yet.

This new table component layout also provides more room under the table to place the interface without introducing a safety hazard. The resulting interface placement on the new body is shown in yellow on the right.

The next appendix will go into the development of the third part of the concept, the Interface.

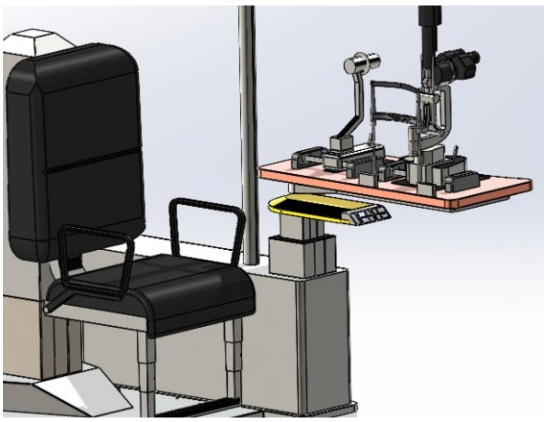


Figure 8-61: New table layout & interface body in yellow

Appendix 18 : Interface design stages

In this appendix, I will explain the design process that led to the final interface design.

Appendix 18.1 : Lo-Fi Sketching

The interface design started with the initial concept, described in Appendix 8Appendix 15 :. The early scenario sketch shown in the top left of Figure 8-62 below, was for this initial concept. As shown in this selection of ideation sketches, I considered several types of interaction for equipment positioning, such as foot pedals, digital interfaces, switch buttons and rotary knobs. In the early stage, I decided on a rotary button, for its high ease of use.

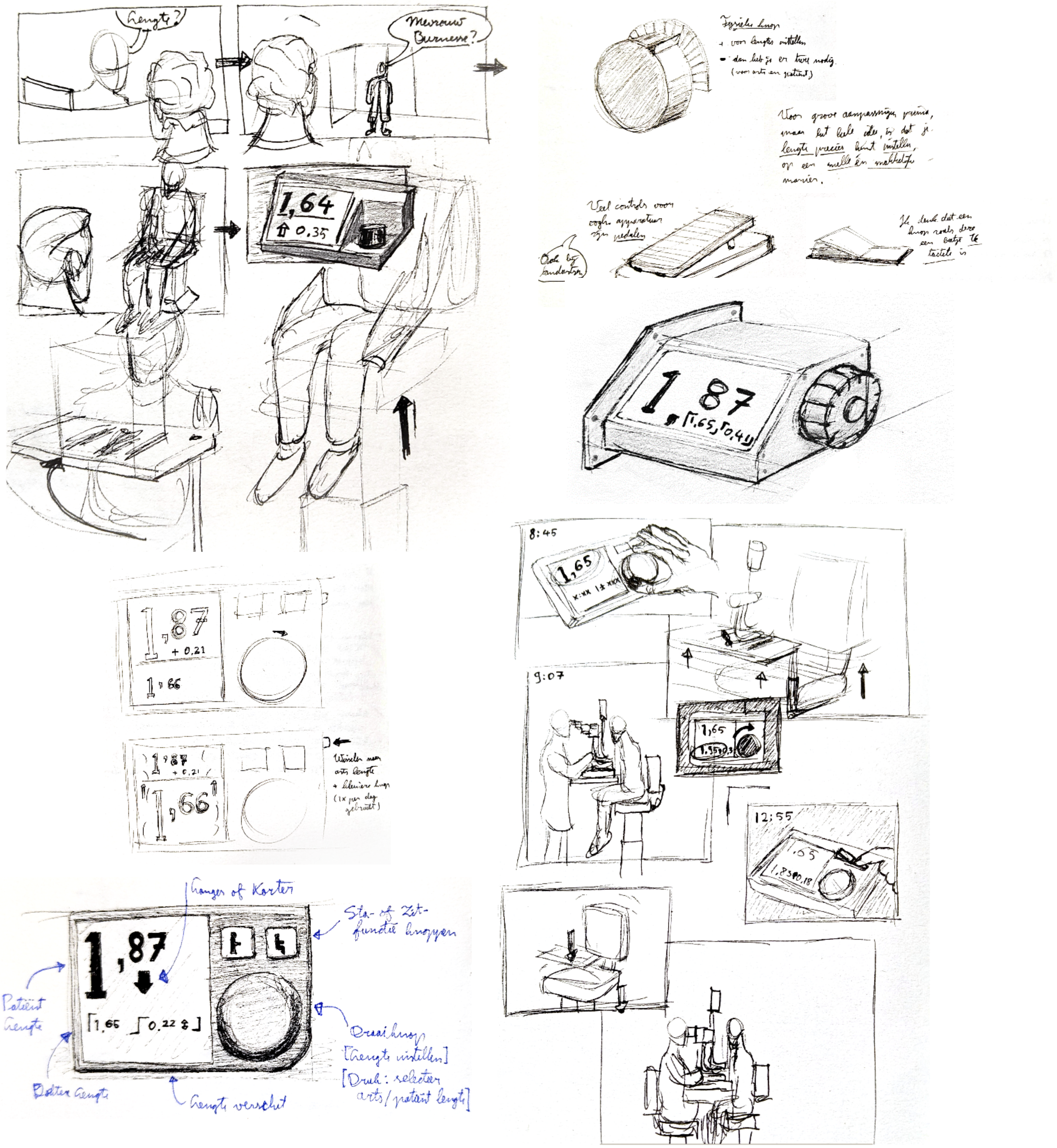


Figure 8-62: Early interface and scenario sketches (selection)

Appendix 18.2 : Digital Sketching

As shown the figures below, I carried the sketch interface from the bottom left of Figure 8-62 (previous page) into digital ideation. I later lost the rotary button for height adjustment as it would likely lengthen the interaction for the user.

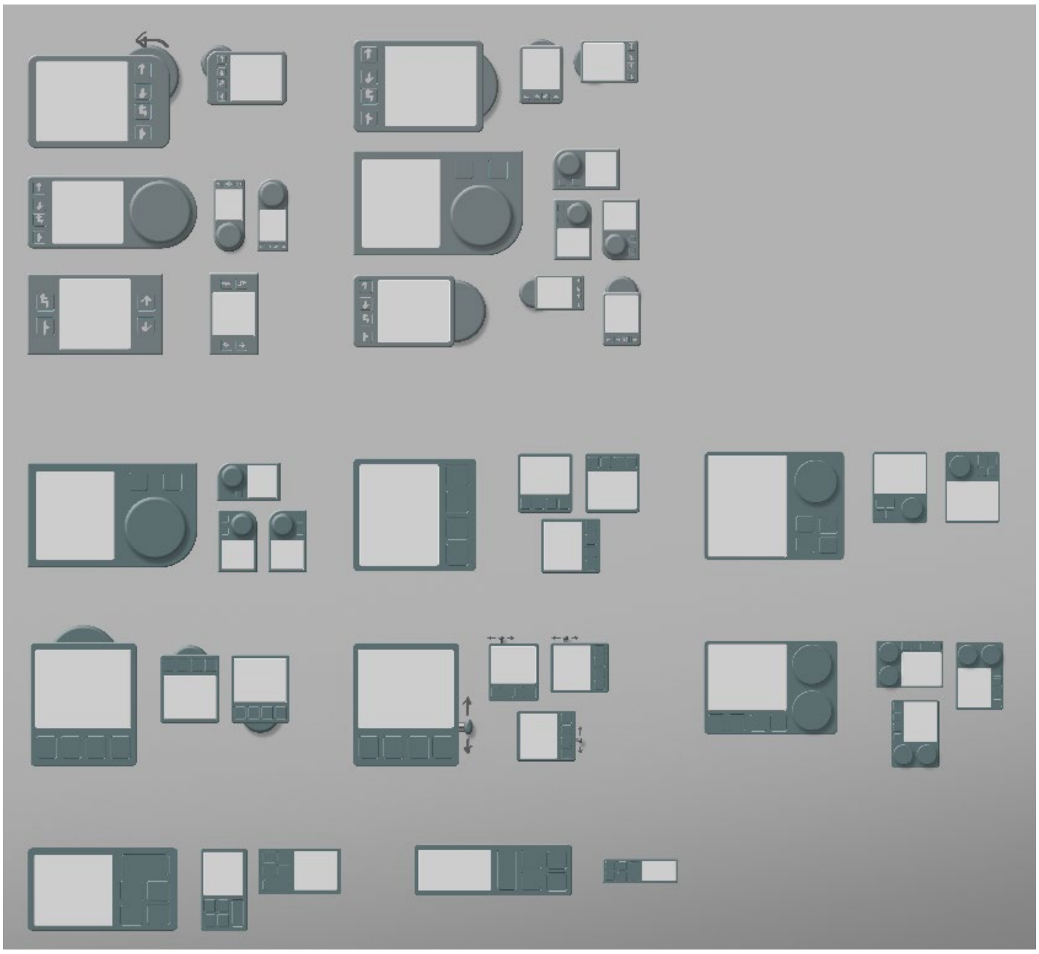


Figure 8-63: Digital Interface ideation A

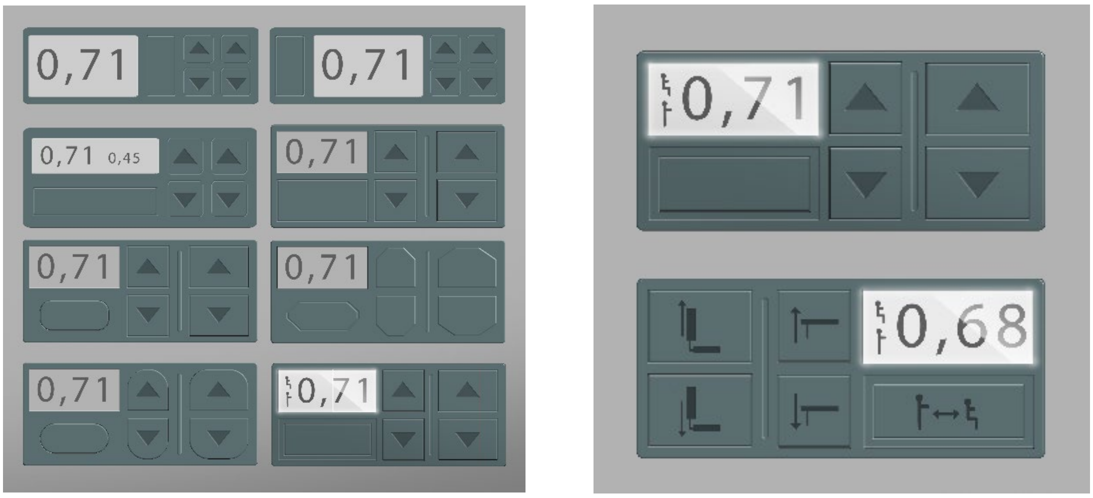


Figure 8-64: Digital Interface iteration B & C

As shown in Figure 8-64 (B), I chose the direction of a more conventional button panel, iterating on the design in terms of button shapes and separation. Further development, from the top to the bottom design in Figure 8-64 (C), was influenced by the user tests (Appendix 8Appendix 19 : & 8Appendix 20 :):

- Button placement was improved by putting the most used buttons closest to the user. From the perspective of the ophthalmologist, slit lamp tables most often slide in from the right as shown in Figure 8-65. When the patient is sitting in the chair, the table on the right slides in front of them with the push of a button by the ophthalmologist. Therefore, with the panel fixed to this table, the left side of the panel will be closest to the user. This iteration was in response to a comment from the second user test.
- Furthermore, the interface conveys the magnitude of the function effect in the size of the corresponding button. For instance, the patient chair height buttons move said chair up with greater steps, and thus have a larger magnitude than the slit lamp table adjustment buttons, which needs to be adjusted with more precision, and with more time available. For this reason, the patient chair height adjustment buttons are larger than the others.

Figure 8-65: An ophthalmological clinic room

- As before, the buttons controlling the slit lamp table height, are next to the screen, showing the current height of said table.
- The current mode, sitting or standing, is indicated in the screen as well, with the mode switch button directly under it.
- The generalised up/down arrows have been replaced by symbols representing their function, to shorten initial adoption.

With the comments from the user tests, as well as the NOG conference, I made another change to the interface. I learned that the chair needs to be able to move backwards and forwards to accommodate patients more completely. The next version of the interface is shown in Figure 8-66, also including a previously omitted table engage button on the left.

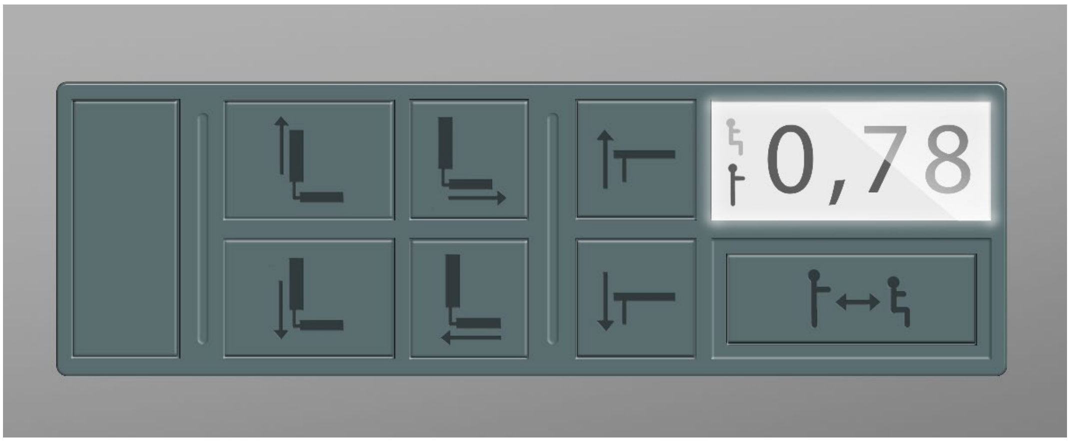


Figure 8-66: The final version of the interface

Appendix 18.3 : Two-split design & 3D modelling

As described in the main part of the report, the concept's slit lamp table moves along a rotational path, shown in the figure below, as opposed to the current linear path. This is chosen to reduce the unit's footprint.

For this reason, the interface has to change too as in the previous configuration, the interface will be turned away from the ophthalmologist when the table is disengaged (encircled in the figure in red).

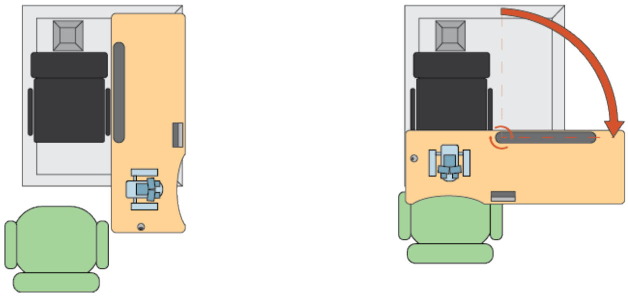


Figure 8-67: Initial linear table movement (1) and new rotational table movement (2)

The devised solution for this, is a secondary engage button on the head of the table (encircled in the figure in blue). This new engage button is shown in the figure below on the left.

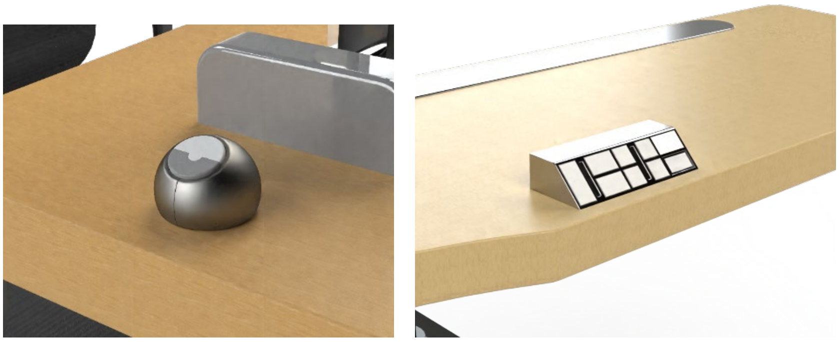


Figure 8-68: New Engage button (left), and Main Interface

The engage button embodies two functions. It is used after the patient sits down. By pressing the top white button, the ophthalmologist makes the table rotate in front of the patient, after which the table/chair combination is raised into standing mode. By pressing the bottom grey button, the table rotates in front of the patient, but the unit stays in sitting mode. Further height and depth adjustments, as well as disengagement (unit back down & table rotates away to let patient out), is subsequently controlled with the main interface Figure 8-68 (right).

This two-split interface concept was later abandoned for several reasons.

- By splitting the interface in two bodies, you run the risk of confusing the user. As the initial interaction is performed with the engage button, it would be reasonable to assume, wrongly, that to disengage, the same action is repeated, as this is how the engage/disengage interaction is currently performed with existing slit lamp tables.
- Currently, the depth (forward/backward) of the chair is adjusted before the slit lamp table is engaged. The common reason to adjust the forward dimension of the chair, is for people with a sizeable stomach. If the table is engaged first, before adjusting depth, the table bumps into the patient's stomach when sliding in from the side. This would equally be the case with the rotational table movement, albeit bumping into the patient from the front. Therefore, as the depth controls need to be presented to the ophthalmologist at all times, this not being the case with the two-split design, the design needs to be complicated further. Solutions within the two-split direction were devised, but none were judged to be effective enough to warrant keeping the two-split.

Appendix 18.4 : Tabletop interface

The next interface positioning was influenced by the realisation that it is unnecessary to have the interface on the slit lamp table top. The interface in current alternatives is never on the table top, but instead fixed to a separate unit body, or the desk.

By fixing the interface to the separate desk in the concept as well, it can remain a single body, as opposed to being two-split.

Figure 8-69: Control panels

The final table/chair design does not provide a body to attach the interface to, but the computer desk, present in every single ophthalmic room, provides a fitting alternative.

Appendix 18.5 : Interface attachment

While attaching the interface onto the desk seemed logical, the interview with an industry representative (Appendix 22) disproved this statement. With the interface attached to the desk, when the ophthalmologist moves from the desk to the slit lamp table, they generally can't reach the interface anymore. With the necessity to access the interface at all times during the examination, this configuration now does not make sense. Because of this conclusion I did another ideation cycle to design a new place for the interface, which is described more in Appendix 17.4. This new attachment point for the interface is shown to the right.

Appendix 19.6 : Colour, Material & Finish

A short ideation session was done to decide on the final colour, material & finish.

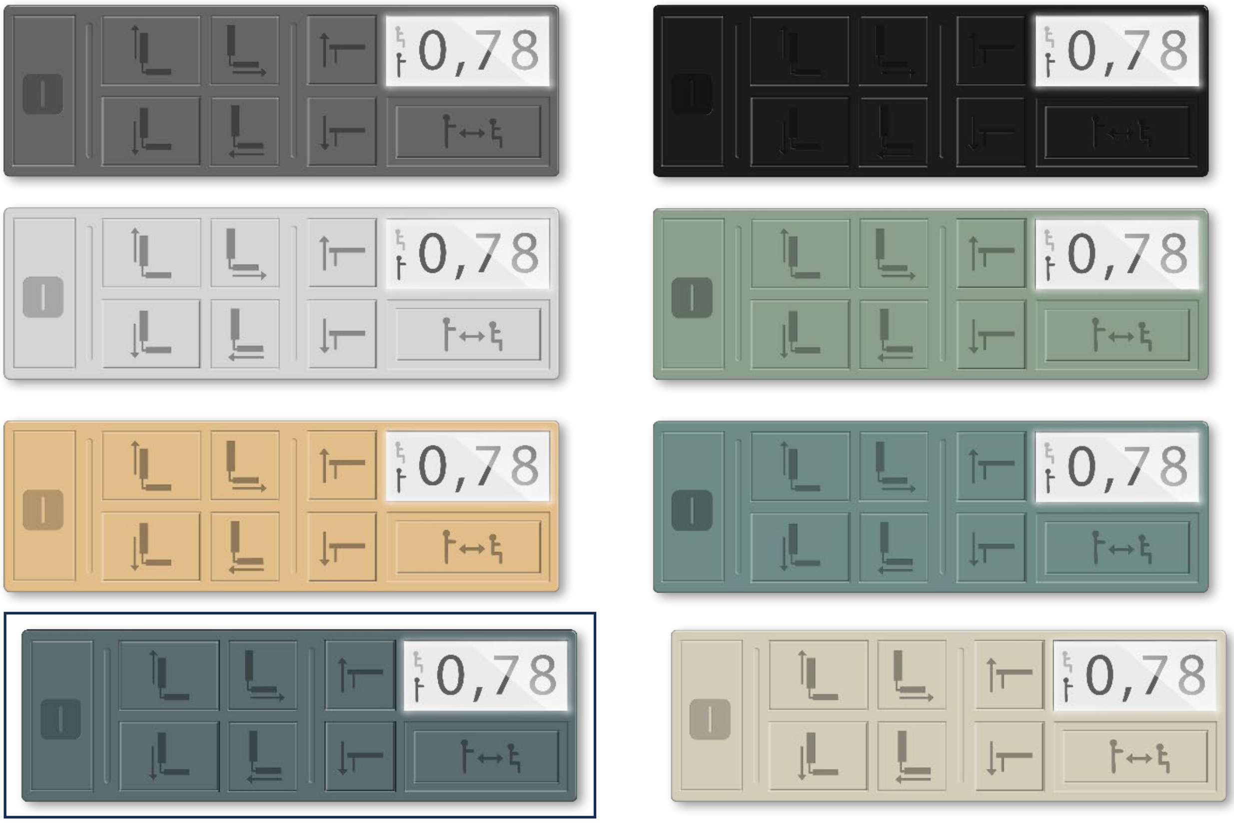


Figure 8-70: Interface Colour variations

A variation of dark blue was deemed to be most appopriate, as it is both conspicuous in the medical context that is defined by the greyscale palette, but still blends in enough to be fitting.

Figure 8-71: Interface Finish variations

A matte surface finish was deemed to be most appopriate as it reduces glare, compared to a gloss finish but still looks more refined than a brushed or sand blasted finish.

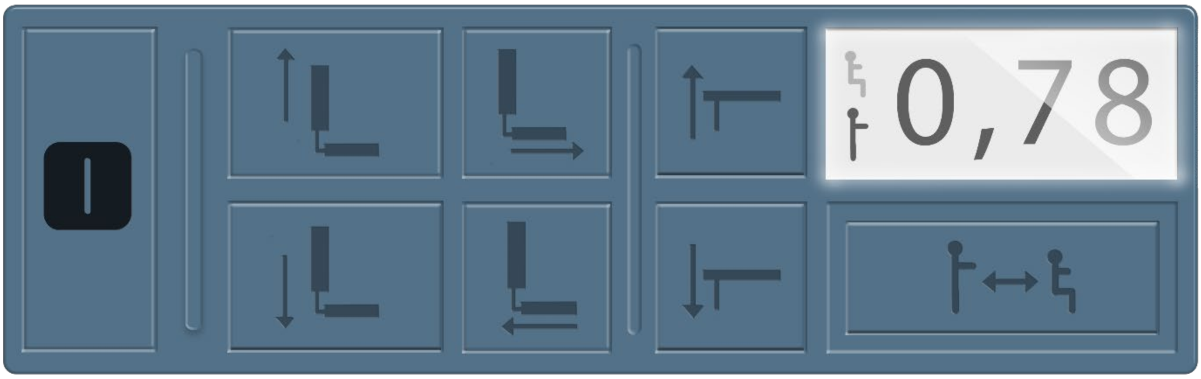


Figure 8-72: Interface with stronger differentiation between engage button and rest

Finally the engage button on the left was made to stand out more by intensifying the icon colour and slightly increasing its distance to the rest of the buttons. This further differentiates it from the others, as this button is used the most. The increased distance also reduces the chance for an ophthalmologist to absent-mindedly push the patient chair buttons, when intending to aim for the disengage button.

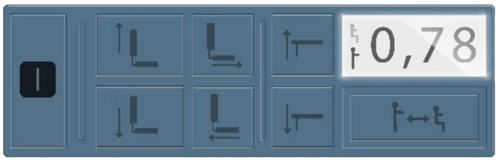
Appendix 19.7 : Providing clarity

The results of the third user test resulted in several design guidelines. The most important take-away was that the interface should provide more clarity for the user. This can be done by connecting buttons that have connected functions, clarifying icons, and more effectively use indentations to group panel elements.

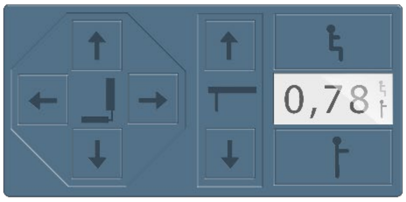
I considered in what products a set of movement in four directions is already controlled. The simple answer, is game controllers. These four-way buttons very clearly indicate their function through their shape. I took inspiration from this in the subsequent iteration.

Figure 8-73: Game controllers already control a set of movement in four directions (Photos by Joshua Oluwagbemiga & Sean Stone on Unsplash)

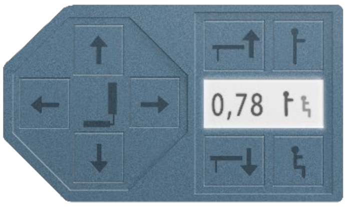
The iteration process is shown on the right, starting with the existing interface that was tested in the third user test.



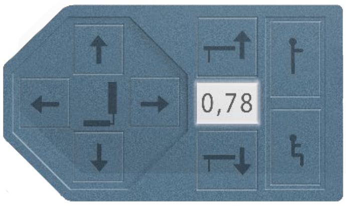
Secondly is the initial inclusion of the four-way button lay-out. In this iteration I also attempted to clarify the spatial relationship between the screen icons and the buttons that relate to them.



The cut-out on the left of the panel was made to further accentuate the four-way button group. Additionally spacing of the screen icons and their respective interaction buttons was improved.



I considered removing the sitting/standing icons from the screen entirely but finally decided against this as this didn't improve clarity as much as expected.



The figure below shows the Interface with its final CMF (Colour, Material, Finish) in context. This CMF is chosen to be more congruent with the larger concept. The surface above it for instance, an end cap on the metal interface supporting body, is made of rubber as it is naturally resistant to coming loose. By making the interface panel the same colour, it falls into place better visually. The buttons keep the matte metal finish outlined earlier. To both introduce a feeling of robustness, and also reduce glare.

Figure 8-74: The Interface with its final CMF (Colour, Material, Finish) in context

Appendix 19 : User test 1 script & transcript

After conceptualisation, I conducted two user tests with ophthalmologists in their clinics. This appendix includes the first test. The next appendix includes the second test.

The goal of these tests was to assess the intuitiveness of the interface design. Intuitive design is meant in the description by IDF (2024), where '*a user is able to understand and use a design immediately—that is,* without *consciously thinking about how to do it*'.

The research question for these two tests is:

Is the design intuitive enough, that it needs little to no explanation for the user to use it effectively?

This was tested by placing the interface and measuring stick in their intended positions on the slit lamp table and beside the door respectively, and asking an ophthalmologist to perform a set of interactions with it. If the ophthalmologist's interactions line up with the intended interactions, this makes it likely that the interface is designed intuitively.

The answers and comments from the respondent ophthalmologist are included in *blue*. My return questions are included in *italics*.

Table 8-27: Respondents characteristics

Institution	Type of Institution (1. Hospital, 2. ZBC, 3. UMC)	Gender (m, v, x)	Years in profession (incl. other employers)	Respondent Nr. (User tests)
IJsselland Ziekenhuis	1. Hospital	V	19	1

Appendix 19.1 : Script

As an introduction to the test I asked the ophthalmologist to read the research chapter as preparation. I then give another brief introduction on how an Industrial Design project typically goes.

1. Find a problem
   In this project this was the NOG brief and subsequent reframing
2. Determining scope
   How do I see the problem and which part of it do I want to solve
3. Goal setting
   A general goal for the project is formulated, as well as a main research question
4. Guided by this research question and sub questions, you do research to get immersed in the problem context
5. After sufficient knowledge and understanding has been generated, design solutions are generated to solve the problem. This knowledge gathering and solution generation to a large degree happens in parallel.
6. A well based decision is made for one solution idea, which is subsequently developed into a concept, considering interaction, construction, manufacture etc.
7. User testing in-context is done to confirm the concept's validity, further iterations are made to include the findings from the test.

This is the framework for this project, which started with the brief from NOG: '*… a graduation project with* […] *a focus on prevention of work-related musculoskeletal injuries*'. My design goal hence became: *Design a solution that will improve the long-term wellbeing of Ophthalmologists by improving the physical ergonomics of their daily, work-related activities*.

The research conclusions this concept was built on are as follows:

1. Shoulders, back and neck complaints are by far the most common among ophthalmologists
2. This is among others caused by high workload, causing neglect of personal health
3. The working in many different rooms equally can have ophthalmologists lose motivation to adjust the equipment
4. Many doctors adapt equipment to the patient, instead of themselves
5. Height difference between patients and ophthalmologists is often considerable, which is problematic as the eye need to be in line for examination

What I understand from this is that a lot, in terms of ergonomic equipment adjustment, is possible, but that it is (a) too little, (b) takes too long, (c) and takes too much effort.

I then take a moment to put the prototypes in place, after which commencing with the first question.

Test question 1: What do you think the purpose of these two objects is?

> If the respondent answers correctly: a measuring device and a new unit interface, the next question is asked. If the respondent answers incorrectly, the prototypes' purpose of measuring the eye height and controlling the chair and table, are explained first.

Test question 2: And how would you use this measuring stick?

> If the answer to this question lines up with the intended use, it is taken to be an intuitive design.

Elaboration is then given on the concept: Many people know their height, but few know their eye height, which is the important metric in this context. By accurately knowing your own eye height as an ophthalmologist, you can adjust the equipment to yourself better, and faster. You measure that eye height with the measuring stick next to the door. Furthermore, height adjustability of patient chair and SL table is centralized in this small control panel. The main advantages to this concept then are:

- Expanding: More height adjustability with a greater reach so that you can always work comfortably, even while standing
- Simplifying: Clearer and more intuitive controls
- Accelerating: Faster adjustment so that the adjustment is actually made

The current interface is quite elaborate, I have tried to simplify it is this small panel (shown in Figure 8-77). The functions have remained the same, when compared to the current alternative, but the interface is improved upon. The main addition in terms of functionalities, is the ability to switch between sitting and standing mode.

Test question 3: What do you think is shown on the screen?

Test question 4: What do you think the two buttons right of the screen do?

Test question 5: What do you think the two buttons on the very right do?

Test question 6: As I said you can work while standing as well, how would you switch to standing mode?

Appendix 19.2 : Transcript

Test question 1: What do you think the purpose of these two objects is?

> *Yeah it's a measuring stick, probably to better adjust to my height. And the other thing is a new button panel?*

Test question 2: And how would you use this measuring stick?

> *I would assume the hole is to look through? So you bring that up so you can look through it. The eye hole is too close to the wall though. If you try to see through that, your shoulder has to be in the wall.*
>
> [in the process of the test, the slider was walked into, as it sticks out]

[The elaboration is now given on the concept]

Yes, you measure that eye height once, which is now also done with the PD (pupillary distance), for example. Distance between your pupils is relevant to properly adjust the slit lamp eyepiece. Every ophthalmologist knows their own PD by heart.

[When she said this, she noticed that her eyepiece was not adjusted properly at all. This shows that proper adjustment of the equipment does not always happen and is not always visible at first glance]

I also think that, just adjusting everything correctly once and then keeping it like that, will also result in some awareness. I then know it's correct and I won't have to make adjustments for the rest of the day. I is still important though, to be able to finetune the heights if necessary.

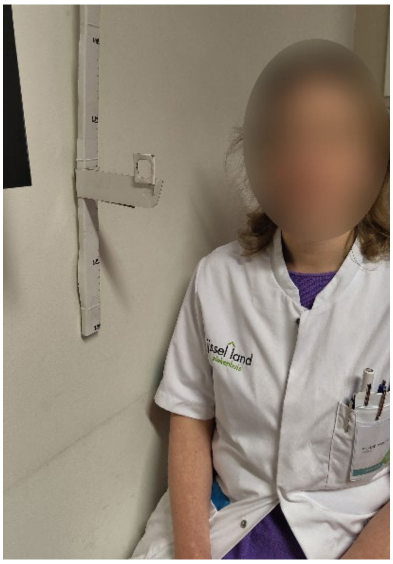


Figure 8-75: Ophthalmologist using the prototype

[Before I mentioned it, the respondent mentioned that working while standing would be great and that another doctor in the department, who is also a physiotherapist had already suggested this once)

I would now like to talk about this new interface. The current interface is quite elaborate, I have tried to simplify it is this small panel (shown in Figure 8-77). The functions have remained the same, when compared to the current alternative, but the interface is improved upon. The main addition in terms of functionalities, is the ability to switch between sitting and standing mode.

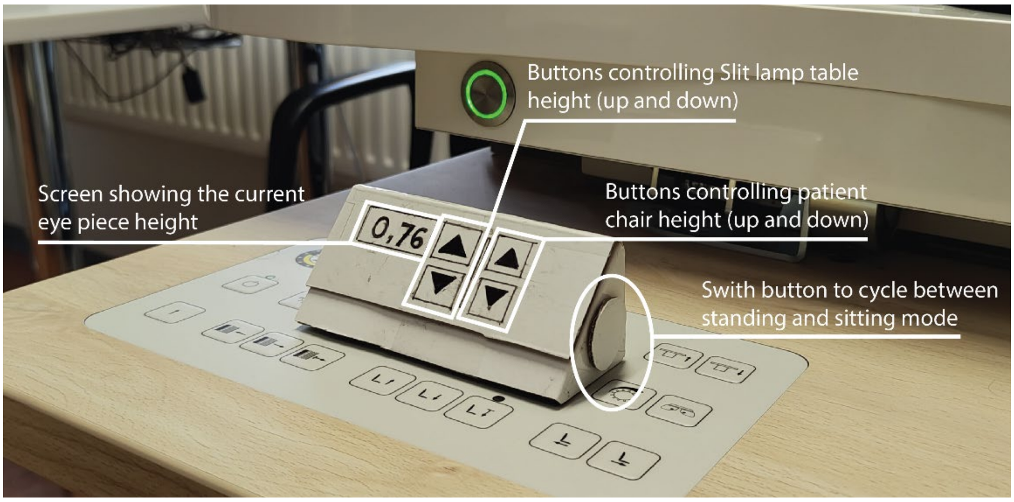


Figure 8-76: The interface control panel at the time of the first user test

Test question 3: What do you think is shown on the screen?

> *So what number is on this? I assume I match that with the measurement I just took*

Test question 4: What do you think the two buttons right of the screen do?

> *So you match that number with your own eye height, I assume the buttons next to it control that? So they set the height of the table*

Test question 5: What do you think the two buttons on the very right do?

> *I'm not sure*
>
> *So these two buttons control the patient chair height*
>
> *I see, I wouldn't have known that right away, but it makes sense now that I know it.*

Test question 6: As I said you can work while standing as well, how would you switch to standing mode?

> *I'm not sure*
>
> *You can cycle from sitting to standing mode with the button on the right side*
>
> *I hadn't even seen that button actually, as it's on the side. But multiple modes, that's kind of like the patient chair in the operating rooms. These operating room chairs already have multiple height settings that you can cycle through with a keypad. You can also control those with a foot pedal, now in the operating room, that's necessary, as your hands are occupied, but in the clinic, most doctors prefer hand panels*
>
> *Why is that?*
>
> *The pedal for patient chair controls is not that popular, because you already control the lamps and table with the hand panel. So then if you're already there with your hand, you're not going to control the other with your foot. The hand panel is just more practical.*

Appendix 19.3 : Results

This paragraph contains the results from the first user test.

Concerning the measuring stick:

1. Little explanation was needed for the measuring interaction
2. The pupillary distance measurement is a measurement that is done for every new ophthalmologist.
3. With the ophthalmologist standing with their shoulder toward the wall, they could not reach the measuring stick's eye hole as it is too close to the wall.
4. The slider was walked into several times during the test, as it sticks out from the wall

Concerning the interface:

5. The multiple similar buttons on the interface panel caused confusion as to their intended function
6. The respondent did not notice the mode switch button at first, as it was out of sight, in its position on the right side of the panel body
7. A hand panel is deemed more convenient than a foot pedal, for controlling the unit

Appendix 19.4 : Conclusion

In this paragraph, conclusions are drawn from the research results, to answers the research question.

Concerning the measuring stick:

1. The measuring interaction is fitting in the context. By doing this at the same time as the pupillary distance measurement for new ophthalmologists, it fits seamlessly into the existing context.
2. The eye hole in the measuring slider needs to be further from the wall to be used effectively
3. The slider should be made to be collapsible, so that users do not walk into it when not using it

Concerning the interface:

4. The control panel being hand operated, as opposed to foot operated, is fitting
5. More differentiation needs to exist between the buttons on the interface to communicate their functions
6. The mode cycle button should be on the front of the panel, as opposed to the right side as previously envisioned, as this right side is out of the ophthalmologist's line of sight. Most ophthalmologists' rooms are laid out with the doctor on the left, with the patient and slit lamp table on the right

Considering the above conclusions, the measuring interaction can indeed be called intuitive, or needing little to no explanation for the user to use it effectively, albeit with a slight alteration of the physical product. The same could not yet be said for the interface. The problems outlined in the conclusions above were attended in the next iteration, including more differentiation between the patient and table buttons, and a repositioned mode switch. The new version was tested in the second user test.

Appendix 20 : User test 2 script & transcript

The goal of the second user test was to assess the intuitiveness of the iteration on the interface design, that was made as a result of the findings form the first test.

This was again tested by placing the interface and measuring stick in their intended positions on the slit lamp table and beside the door respectively, and asking an ophthalmologist to perform a set of interactions with it. If the ophthalmologist's interactions line up with the intended interactions, this makes it likely that the interface is designed intuitively.

The answers and comments from the respondent ophthalmologist are included in *blue*. My return questions are included in *italics*.

Table 8-28: Respondents characteristics

Institution	Type of Institution (1. Hospital, 2. ZBC, 3. UMC)	Gender (m, v, x)	Years in profession (incl. other employers)	Respondent Nr. (User tests)
Franciscus Gasthuis / Vlietland	1. Hospital	M	22	2

Appendix 20.1 : Script

As an introduction to the test, the ophthalmologist is again asked to read the research chapter as preparation. I then give another brief introduction on how an Industrial Design project typically goes. This is the same as the introduction given in the first test, and is therefore not repeated here.

I then take a moment to put the prototypes in place, after which commencing with the first question.

Test question 1: What do you think the purpose of these two objects is?

> If the respondent answers correctly: a measuring device and a new unit interface, the next question is asked. If the respondent answers incorrectly, the prototypes' purpose of measuring the eye height and controlling the chair and table, are explained first.

Test question 2: And how would you use this measuring stick?

> If the answer to this question lines up with the intended use, it is taken to be an intuitive design.

The same elaboration as in the first test is then given on the concept: Many people know their height, but few know their eye height, which is the important metric in this context.

[see previous appendix for full elaboration]

The main addition in terms of functionalities, is the ability to switch between sitting and standing mode.

Test question 3: What do you think is shown on the screen?

Test question 4: What do you think the two buttons right of the screen do?

Test question 5: What do you think the two buttons on the very right do?

Test question 6: As I said you can work while standing as well, how would you switch to standing mode?

Appendix 20.2 Transcript

Test question 1: What do you think the purpose of these two objects is?

I assume it's a measuring device to get my eye height? You're talking about height in this concept so that probably helps to better adjust the equipment

Test question 2: And how would you use this measuring stick?

Probably by sliding the eye hole up to your eye

[Elaboration on the concept]

That's interesting. So you take that measurement of yourself and then adjust the equipment with that. See, I am quite careful with equipment adjustment already. I come here early to prepare everything properly, but with this, that should actually go quicker. Nice.

You could also do that measurement at the same time as PD, pupillary distance, new ophthalmologists always need to get theirs measured to adjust the eyepiece, so you could do this at the same time.

I call it that you have to work as 'uncompensated' as possible, adjust all the stuff perfectly to yourself so you don't have to bend, extend, etc. with the PD, you know how to set that, so having that for the rest, like this, would be handy.

And yeah I definitely like the idea of standing working, you just have to be careful the patient can't fall out but that should be fine with the table in front of them.

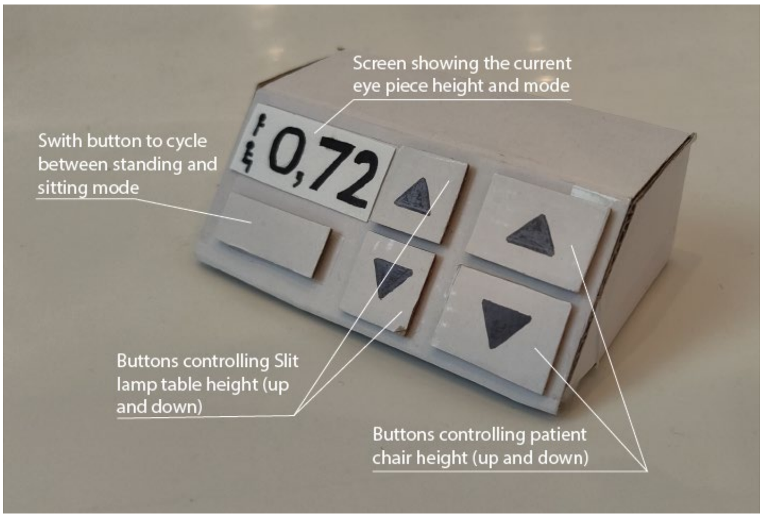


Figure 8-77: The interface control panel at the time of the second user test

Test question 3: What do you think is shown on the screen?

So the number is the eye height?

Yes, so the screen shows the eyepiece height.

Makes sense, so change that to your own eye height then.

Test question 4: What do you think the two buttons right of the screen do?

I would say the buttons on the left are for the patient and on the right for the table. [incorrect, compared to design at the time] *You want the buttons you use the most closest to you, so on the left.*

Test question 5 What do you think the two buttons on the very right do?

[not asked as it's answered in previous answer]

Test question 6: As I said you can work while standing as well, how would you switch to standing mode?

Probably this button [while pointing at the (correct) cycle button]

Follow-up question: Your answer differed from the way I designed the interface, what button layout would make more sense to you?

Well the patient controls should be on the left, as that is always closest to you, most slit lamp tables come from the right. But the screen should still be closest to the table buttons as those correspond. Mirroring the whole thing could be good.

Also remember you can control the depth of the chair, so how far away it is from you, separate to the height. If someone's stomach is larger, this can otherwise impede them from reaching the chin rest.

Appendix 20.3 : Results

This paragraph contains the results from the second user test.

Concerning the measuring stick:

1. Little explanation was needed for the measuring interaction
2. The pupillary distance measurement is a measurement that is done for every new ophthalmologist, reconfirmed

Concerning the interface:

3. A hand panel is deemed more convenient than a foot pedal, for controlling the unit
4. The respondent expected the most used buttons to be on the left, that is closest to them
5. The ophthalmologist was missing the functionality to adjust the chair forward and backwards, which is necessary to examine more corpulent patients

Appendix 20.4 : Conclusion

In this paragraph, conclusions are drawn from the research results, to answers the research question.

Concerning the measuring stick:

1. The measuring interaction is fitting in the context. By doing this at the same time as the pupillary distance measurement for new ophthalmologists, it fits seamlessly into the existing context.

Concerning the interface:

2. The control panel being hand operated, as opposed to foot operated, is fitting
3. It is better to have the most used buttons closed to you, meaning on the left of the interface panel, if the interface is attached to the table unit. As table units are generally on the right of the doctor, the buttons on the left of the panel will be closest to the user. Thus placing the most common panel interactions on the left increases ease-of-use.

4. The unit needs to allow the ophthalmologist to adjust the chair's depth (forward and backwards) to allow more corpulent patients to be examined equally

Considering the above conclusions, the measuring interaction can indeed be called intuitive, or needing little to no explanation for the user to use it effectively. The same could not yet be said for the interface. The problems outlined in the conclusions above were attended in the next iteration, including repositioning of buttons to place common interactions closest to the user, and the inclusion of chair depth control. The new version was tested in the third user test.

Appendix 21 : NOG conference

On the 27th of March 2024 I attended the 218th yearly NOG conference in Groningen. This three-day conference is organised every year to bring together ophthalmologists, industry representatives and suppliers to share knowledge and establish contacts. I talked to multiple ophthalmologists, as well as industry representatives and suppliers about my design concept to gather feedback. The conclusions from these conversations are included below.

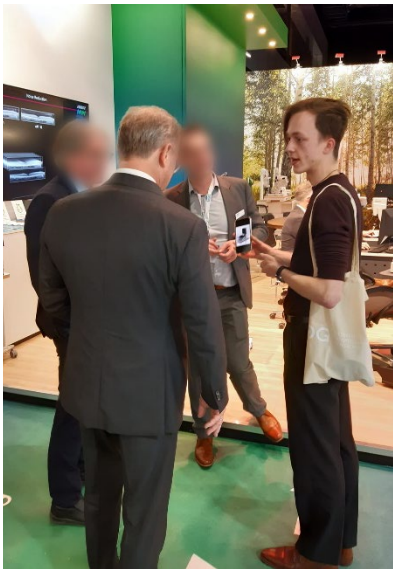
The presentation by the chair of the NOG professional interests committee (Beroepsbelangen Commissie, BBC) once more confirmed that musculoskeletal injuries are a major concern in Dutch Ophthalmology. Estimates range from 30 to 60 % of Dutch ophthalmologists who currently or have previously battled with such problems.

The same presentation elaborated on innovations and new developments in ophthalmology. The field of ophthalmology is becoming increasingly aware of problems that threaten the future wellbeing of its practitioners. For one, current predictions show an increase in need for medical care, caused by an aging population. Simultaneously, large amounts of ophthalmologists are reporting reduced work ability and efficiency due to musculoskeletal injuries. These issues combined make for an expected further increase of work load and pressure on ophthalmologists. In part due to this trend, the conservative field of ophthalmology is more looking for innovations, both in terms of physical solutions and logistical changes, that might help meet the increasing demand.

Figure 8-78: Me, using a Slit Lamp at the NOG conference

These shifts in ophthalmology, and its recent willingness to be progressive, and innovate to find solutions for its problems, provide an argument for support of the concept, presented in this report.

After this presentation, I talked to representatives of several renowned producers and suppliers of ophthalmological equipment. For the sake of impartiality, these parties are referred to anonymously.



Representatives of supplier 1 expressed enthusiasm for the concept, agreeing that this would solve a lot of problems in the context and that it can be produced with existing components and technology. They confirmed that, while the concept's construction, with the posterior raising pilar, requires stronger components and actuators, it is entirely feasible. They also, similarly to the ophthalmologists in the user tests (See User test 2 script & transcript), mentioned the importance of being able to move the patient chair forwards and backwards. They lastly confirmed the conservative nature of the ophthalmological sector. He gave the example of the slit lamp, saying: '*If you were to redesign a slit lamp right now, with the current capabilities, it really wouldn't look like this*'.

Figure 8-79: Me, talking to representatives of Medical workshop

A representative of supplier 2, who supply a large portion of outpatient units in the Netherlands, said his advice to ophthalmologists is always: adapt your device to yourself, and bring the patient to you. This confirms the self-prioritising advice to ophthalmologists, which underlines the concept. Additionally, everything that can be, should be electrically controlled, which is much better for ergonomics. They also showed one of their table units, that includes a standing desk for the computer section. He mentioned this is confirmed to be an ergonomic way of working, but that no such thing exists for the slit lamp side of the unit yet, agreeing that this would be a welcome innovation. He also mentioned the importance of moving the patient back and forward, which was later, once again confirmed by another ophthalmologist. Also, the patient should have a footrest if they move up. Special care should be taken so that the patient's feet can't get stuck under this when the chair moves down.

In talking to a representative of supplier 3, it was confirmed that it is generally preferred to not put arm rests on the patient chair. This is because these can get in the way when moving the chair closer to the slit lamp table. It can however be a patient comfort consideration to include them, and with the greater elevation that the concept chair reaches, they are necessary from a safety perspective. In this case, they need to be collapsible, which is how existing alternatives are designed. Either this or the arm rests are proportioned to not collide with the table, for instance fitting under it.

Below is an alphabetic list of all parties present at the NOG Conference:

Abbvie, Alcon, Apellis, Avanzanite Bioscience BV, Bartiméus, Bausch & Lomb, Bayer, Carl Zeiss, Chiesl, Coopervision, Dorc, Essilor Luxottica, Eye Care Foundation, Glaukos, Haags Kunstogen Lab., Horus Pharma, Hoya, ISTAR Medical, Johnson & Johnson Vision, Koninklijke Visto, Kuijpers Instruments, Laméris, Laservision, Medical Workshop, Menicon, Nexus Nederland, Oculenti, Onspot Medical, Ophtec, Robert Coppes Stichting, Roche, Rockmed, Santen Pharmaceutical, Simovison, SJJ Solutions, Surgicube, Synga Medical, TheaPharma, Tramedico , Ursapharm, Vitaminenoprocept

Appendix 22 : Interview with Industry representative

On 30 April 2024, I interviewed a representative of a medical equipment supplier, using a video call. This supplier is specialised in ophthalmological and ENT equipment for outpatient clinics and operating rooms. They have been supplying the medical sector for 115 years. The representative, anonymous for privacy reasons, is manager operations and has been employed in the company for more than 10 years.

The goal of this interview was to confirm the feasibility of the concept in terms of construction, proportions and dimensions, and its fittingness in the context.

Below is the script I used for this interview, after this is the transcript of the interview, and lastly the conclusions drawn from it.

Appendix 22.1 : Script

I start the interview with an introduction of the project, it's initial goal, and the research conclusions that led the design stage, to provide context as well as a description of the concept, accompanied by visual representations of the design.

The conclusions that really underline this design are;

1. Musculoskeletal injuries among ophthalmologists are exceedingly common and they are most commonly found in the shoulders, back and neck.
2. Ophthalmologists work in different rooms across days and across the day, which reduces their motivation to adjust the equipment every time
3. Ophthalmic equipment is insufficiently adjustable to different doctor and patient heights
4. Ophthalmologists often choose patients' comfort over their own, thus neglecting their own health

My goals during the design process, were therefore to

1. Extending height adjustability in the ophthalmic table/chair unit
2. Speeding up the interaction so that the adjustment is actually made
3. Simplifying the interaction so that the adjustment is actually made

The concept I hence developed is shown in the images below.
(In the interview I showed animations, illustrating the unit's movements. These animations are approximated by the stills below. The animations as well as the pictures were shown using a slide show)

First off all, in my design I include a swivel motion instead of the more common linear motion (swivel rotation axis shown in green in figure below). The reason for this is a reduction in footprint, of the overall unit, as well as a new ability to examine wheelchairs users, by leaving the table in its forward position.

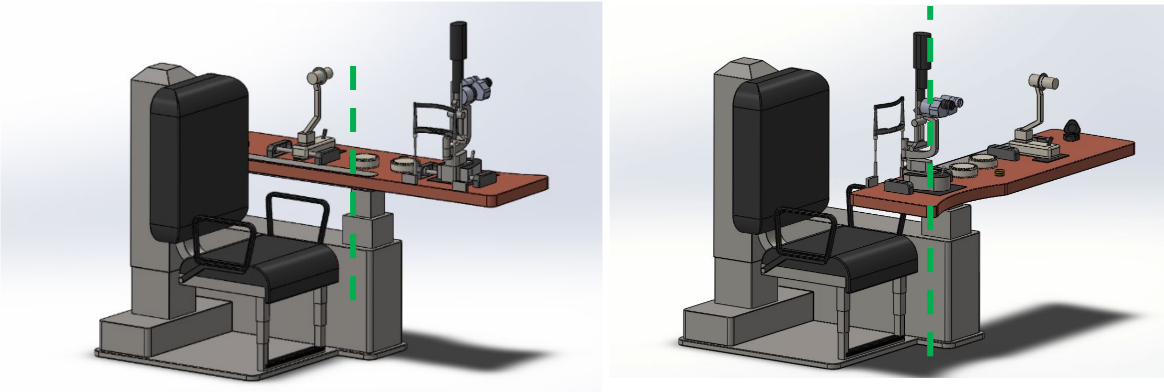


Figure 8-80: Table Swivel motion

Secondly it is possible to elevate the unit much higher, when compared to current alternatives, thanks to the new component layout. This also allows the ophthalmologist to work while standing.

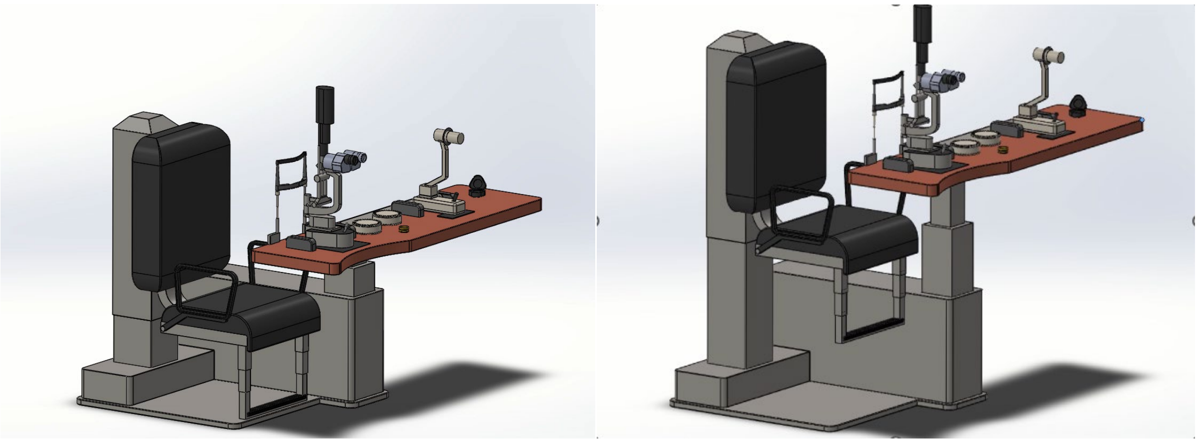


Figure 8-81: Table mode switch to standing mode

Furthermore the table can slide out further to give access to secondary examination equipment.

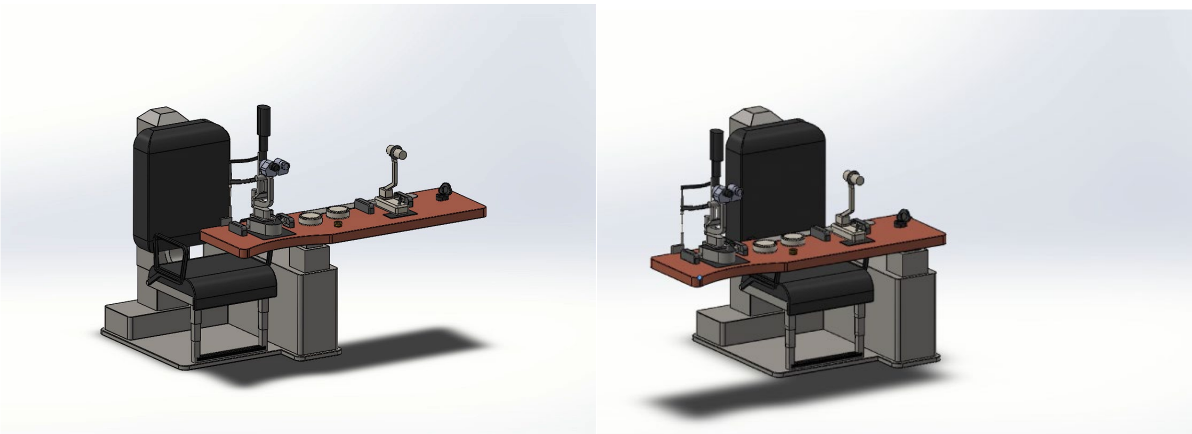


Figure 8-82: Table sideways motion to access secondary equipment

The arm rests can be switched back to facilitate more corpulent patients.

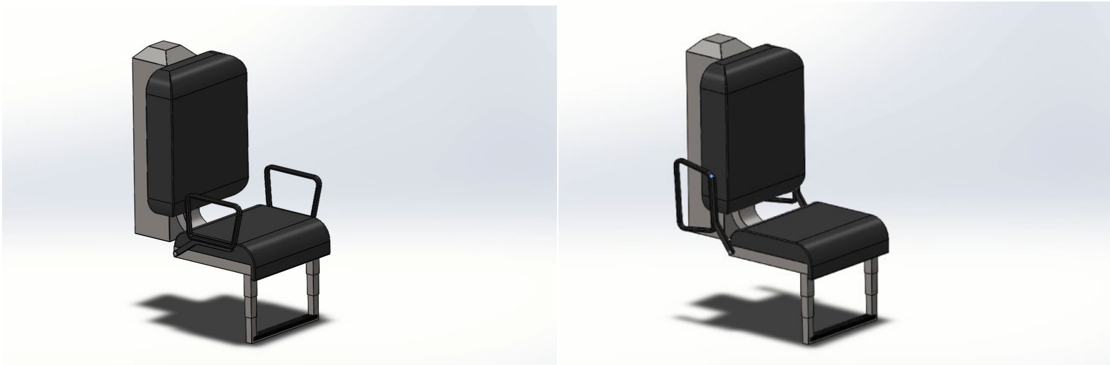


Figure 8-83: Chair armrests movements to accommodate more corpulent patients

And the footrest, which is necessary support the patient when examining in standing mode.

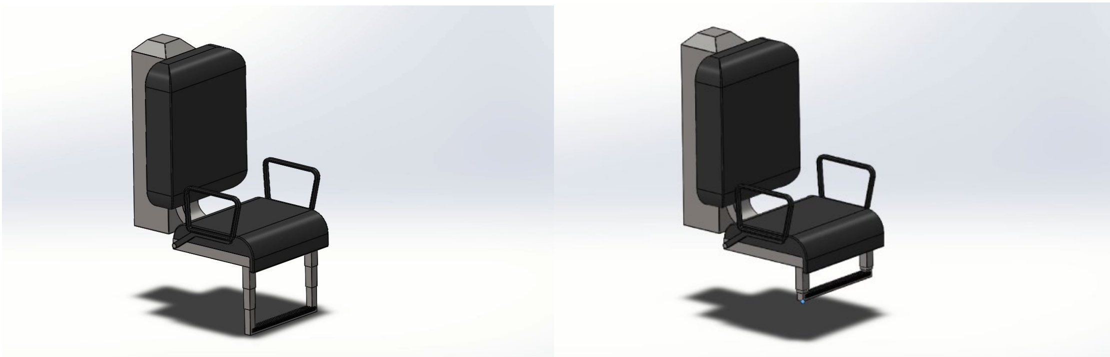


Figure 8-84: Footrest collapsing movement to prevent Achilles heel clipping

At the moment, the proportions of the concept are largely derived from existing alternatives. The block that support the table and holds its actuators, for instance (shown in yellow in the figure below), is based on proportions of existing swivel tables.

Figure 8-85: Reference for table box dimensions

The base plate measurements are based on existing base plates, with a slight extension to increase strength and stability.

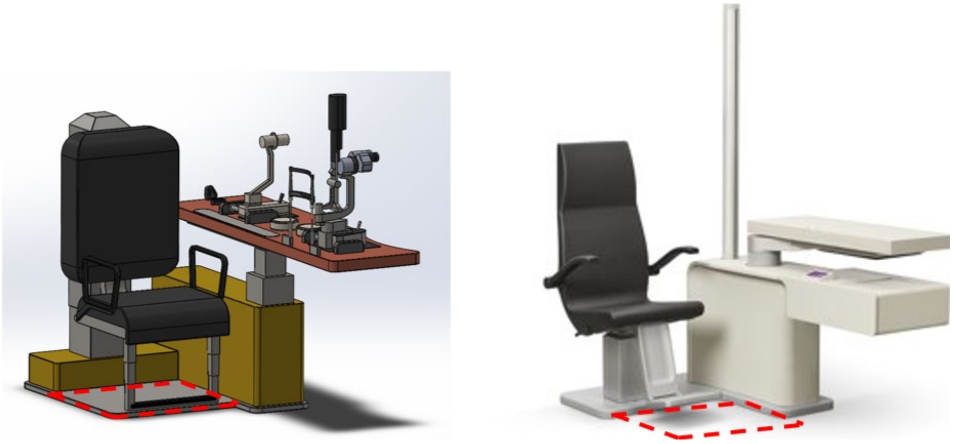


Figure 8-86: Reference for baseplate dimensions and extension to increase strength and stability

The chair proportions (shown in yellow in the figure below), are based on existing chairs.

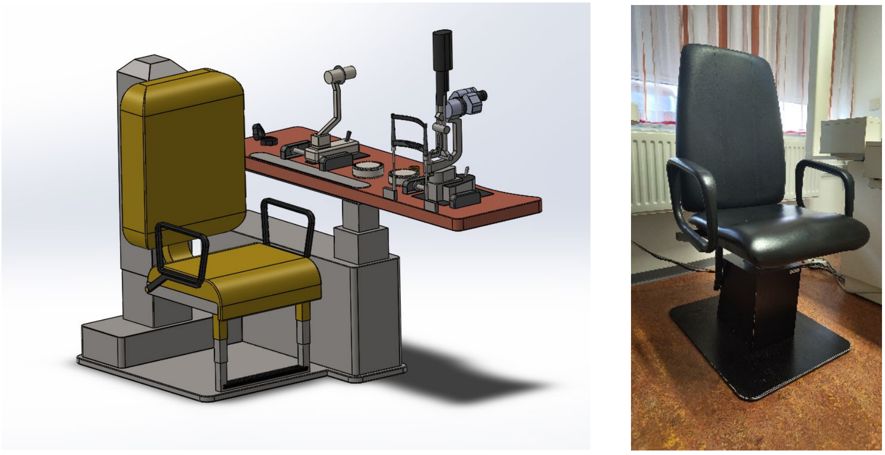


Figure 8-87: Reference for chair diemnsions

Question 1: Why are linear tables so widely used, when compared to other movement types?
The reason for this question, is to find out whether there are advantages to a linear motion table, shown in the figure below, that I was heretofore unaware of. It is valuable to uncover this, as the swivel motion is a central part of my design

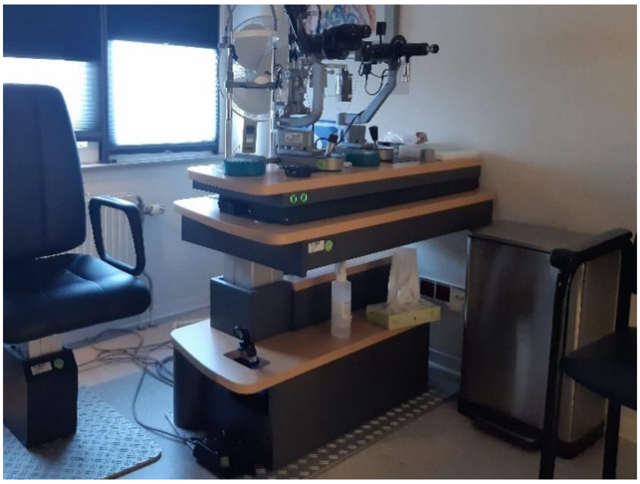


Figure 8-88: A table unit with the common linear movement

Question 2: What is the best place for the interface? (out of option 1,2&3 in the figure, or otherwise)

The reason for this question, is that I have seen the interface placed in different spots within the ophthalmic room, as shown in the figure below, during my research visits. The placement of the interface profoundly influences the use scenario, and has to be well considered. To include the opinion of an industry professional in the design makes the argument all the more robust.

Figure 8-89: 3 spots the interface is seen in

Question 3: Is the posterior pillar feasible in the context?

The reason for this question, is that the posterior column is a central aspect of the design. Further confirming that this component layout is feasible, with a professional that knows the implications of different component layouts, is paramount.

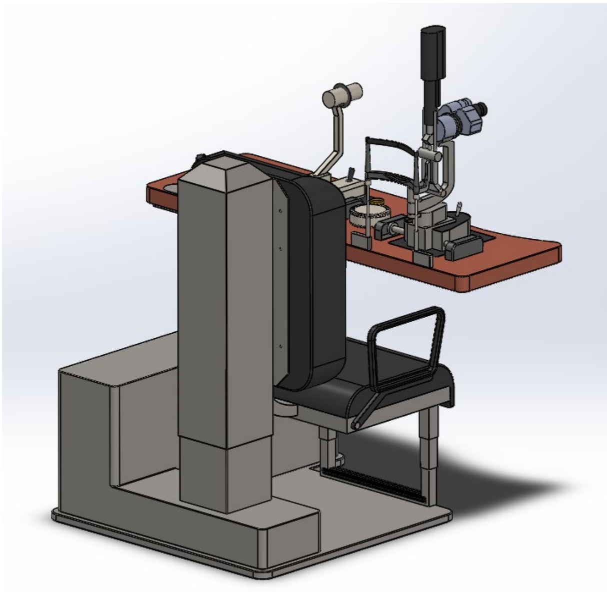


Figure 8-90: Back view of the new posterior column

Question 4: What are the pros and cons when comparing these two base plate options?

When researching existing table units I found two options in terms of base plates (Figure 8-92). Either the chair and table base plates are joined, as seen in the left of the figure below. The other option has the base plates entirely separated, where the table is stabilised by a counterweight, as seen in the right of the figure below. The reason for this question, is that I was as of yet unable to find conclusive reasoning to pick either option.

Figure 8-91: Two different types of base plates: Chair & Table joined, or separate with table counterweight

Question 5: When you look at the design, are there things that need to be considered more, or that have not been accounted for?
This question is asked to uncover any faults in the design that have yet been unnoticed.

Appendix 22.2 : Transcript

The transcript of the interview is included below. The questions are repeated in bold while the interviewee's answers and comments are indicated in blue. The black italics are my answers and return questions.

I started with the introduction described above.

-Transcript-

And do I understand correctly that that swivel movement of the table is electro mechanical?

Yes that's right, mainly to require as little force from the ophthalmologist as possible.

I see, because there are indeed already units on the market that do this, we call it swivel tables. It has a swivel top, so you first swivel it and then slide it in front of the patient, and we don't actually sell them, because we don't think they are good for occupational health and safety.

I see, why is that?

So a manual swivel motion is quite strenuous for the user, and we don't want to provide that.

I see, so you do not provide the manual swivel tables, but you do provide electrically supported ones?

I am not aware of any of these existing. Some swivel tables are advertised to be electric, but then the linear motion of the table is electric, but the swivel motion is still manual. It do think it is feasible to make that movement motorised, but it doesn't exist yet at the moment.

Question 1: Why are linear tables so widely used, when compared to other movement types?

That's because linear tables are, at the moment the only ones with full motorised movement. Others are manually moved, which is more strenuous. You also have linear tables with manual movement, but those are very old-fashioned, and will be phased out.

What you can also see here in this picture, is that the base plate consists of two parts. So chair has a separate base plate and so does your table unit. I would probably advise that for your design as well.

That's because, the unit also has to enter the room and if it doesn't fit through the door, the technicians have to put it on its side. And I think, then they will suffer from neck and shoulder complaints, so keep the footprint as small as possible.

Okay, so it is better to separate the table and chair base plates to make installation a bit easier.

Yes, or make it so the two connect after or during installation. We have that, for example. Our chair and units are ultimately attached to each other, but we do that on site. But that is something to take into account.

Question 2: What is the best place for the interface?

Figure 8-92: 3 spots the interface is seen to be in

For us, the first option you mentioned [1. in the figure] *is standard, so on the stationary body under the table. If you have this setup, as in the picture, we sometimes place it on the desk, because we see that the doctor eventually sits there.*

And when the doctor can simply operate all room functions from there, they actually don't have to make any turning movements. So all you have to do is, operate the PC, then roll a little to the right to carry out the examination and then a little to the left to take a seat behind the desk again.

And generally when it's on the desk, it's attached to it. We also once made it in such a way that the doctor could move it themselves, so they could also choose where to put the control panel. And in this case we always place an extra button on the table, right next to your slit lamp, where you pretty much put the second arrow, for chair adjustment. Just so these adjustments can always be made.

So basically this is because once you go from the desk to the slit lamp table, you can't really reach the interface on the desk anymore?

Exactly, and to keep access to those adjustments, we solve it in that way.

Question 3: Is the posterior pillar feasible in the context?

We always have space behind our patient chair, so you will not need extra space or anything to fit this. And in terms of construction, you would have to do those calculations, but this is entirely feasible.

And the seat can also be moved forwards and backwards?

Yes, that is included in the concept

Ah good, because that is an important feature to keep especially when there are children sitting in the chair or someone who is a bit portly.

Question 4: What are the pros and cons when comparing these two base plate options?

Figure 8-93: Two different types of base plates: Chair & Table joined, or separate with table counterweight

Well, one advantage, if you can really remove the patient chair, is that you can also easily facilitate wheelchair patients.

I see, but what I'm wondering then is, these chairs are rather heavy, the consultations are 10 minutes max, do these chairs really get moved in practice?

Well, the solution we provide is on a rail, so we actually place the chair on a rail, so you can roll the chair to the side and that's less than 10 seconds of work, so that does happen. But the solutions that rival colleagues have, where the chair is moveable on wheels, not on a rail, we don't have those and I don't think it would get moved much then. Purely because the chair is too heavy for that.

And also, counterweights in these units are very common, you know. We have that too. We have 3 blocks of 25 kg each or so in there. That's a very common thing to do. You also have to take into account that patients don't only have weight on their patient chair, but they also lean on the table. So if they have to sit behind the slit lamp, they will really lean their weight on that table top. In your design the table is quite long, so you have to see if that will work.

Question 5: When you look at the design, are there things that need to be considered more, or that have not been accounted for?

For one I would recommend seeing if you can shorten the table, as it is currently quite long to be supported at the end of it.

You also currently don't have a phoropter pole included, I don't think. Phoropters are used to determine someone's prescription. They simply need one of those.

And remember to include some safety feature that prevents the patient's ankles from getting caught under the footrests when moving down

Figure 8-94: Phoropter (Locumotive, 2021)

Appendix 22.3 : Conclusions

Several conclusions were drawn from this interview.

1. While motorised rotation in swivel table units is not currently available, it is deemed realistic in the context of ophthalmic clinics
2. If the interface it is attached to the desk, when the ophthalmologist moves from the desk to the slit lamp table, they generally can't reach the interface anymore
3. Keeping access to patient chair adjustments when examining the patient is preferred
4. The posterior pillar is feasible in the context
5. Backwards and forwards adjustability for the patient chair is an important feature
6. It is best to make the base plates of chair and table separate to ease installation. The two options to make this possible are keeping the two entirely separate, or by having them connect during installation
7. Patients lean on the table when being examined, the table has to facilitate this force. One way to do this, is by shortening the table.
8. It is important to include a phoropter pole
9. It is important to include a safety feature preventing patient's ankles from getting caught under the footrests

These conclusions were instrumental in improving the concept, and fitting it to the concept. The opportunities for improvement uncovered here were improved upon in the next iterations.

Appendix 23 : User test 3

Towards the end of the design phase I conducted a third user test, as the interface design had changed considerably since the previous test (see figures below) The goal of this test was again to assess the interface's intuitiveness and ease of use. This was done by first providing respondents with a short summary of the project, and a description of the concept and its functions. The respondents are then asked to perform a number of actions with a prototype interface. Below is the script I used for this interview, after this is the transcript of the interviews, thirdly are the conclusions drawn from the tests, and lastly what I plan to do with this knowledge.

Figure 8-95: Interface design at second user test

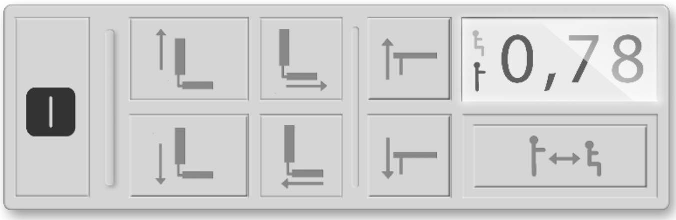


Figure 8-96: Interface design at third user test

The test was conducted with 3 respondents, whom are not ophthalmologists. This was deemed fitting as what is tested, intuitiveness of the interface, does not require ophthalmological background knowledge but rather relies on common logic. Below are the respondents' characteristics for this tests.

Table 8-29: Respondents characteristics

Respondent Nr. (User tests)	Gender (m, v, x)	Age
3	V	25
4	M	23
5	V	22

Appendix 23.1 : Script

A significant amount of ophthalmologists in the Netherlands suffer from musculoskeletal injuries. The goal of this project is to design a solution to improve their long-term wellbeing by improving the physical ergonomics of their daily, work-related activities.

A large portion of their work centres around a 'slit lamp', which allows ophthalmologists to examine patients' eyes. Many musculoskeletal injuries in ophthalmologists originate from the lack of height adjustment possibilities in the slit lamp table and patient chair, and ophthalmologists' tendency to adjust the equipment to their patients' comfort instead of their own.

Figure 8-97: The concept shown to respondents

The concept I hence developed is a redesigned chair/table unit that allows for more adjustment, including a standing working mode. It also makes adjustment easier and faster through the simplified interface, and improved product interaction. The concept is shown in the images below. (In the interview I showed animations, illustrating the unit's movements. These animations are approximated by the stills below. The animations as well as the pictures were shown using a slide show)

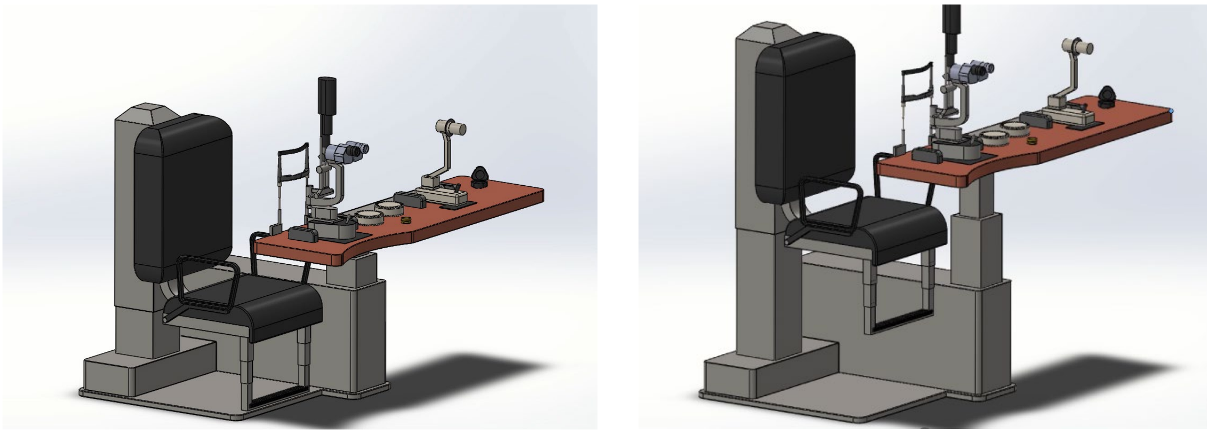


Figure 8-98: Table mode switch to standing mode

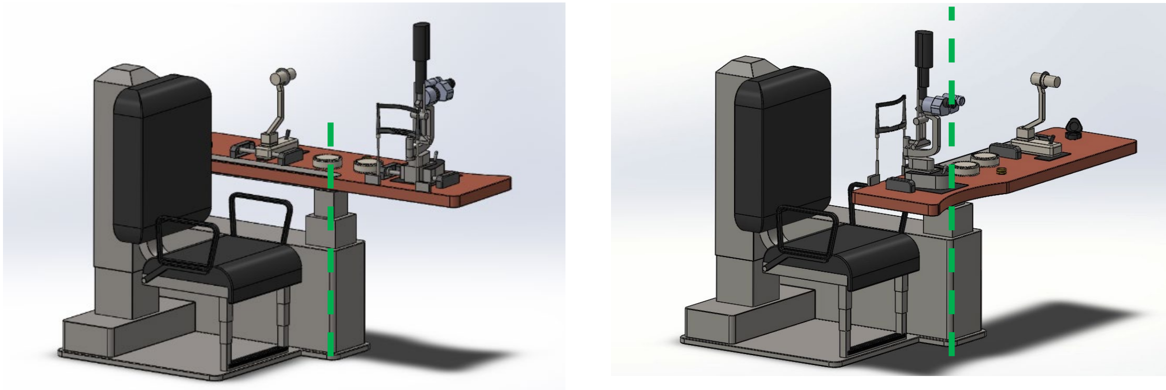
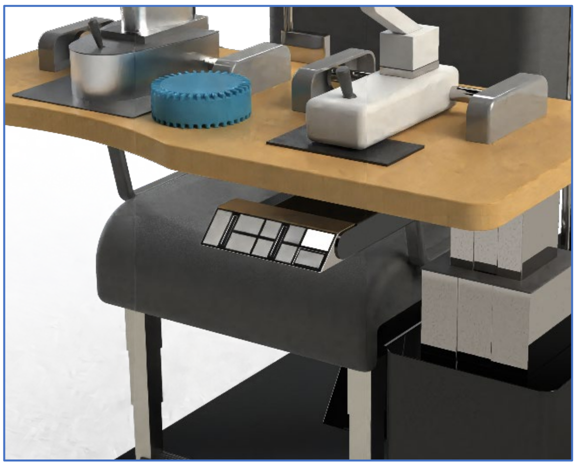
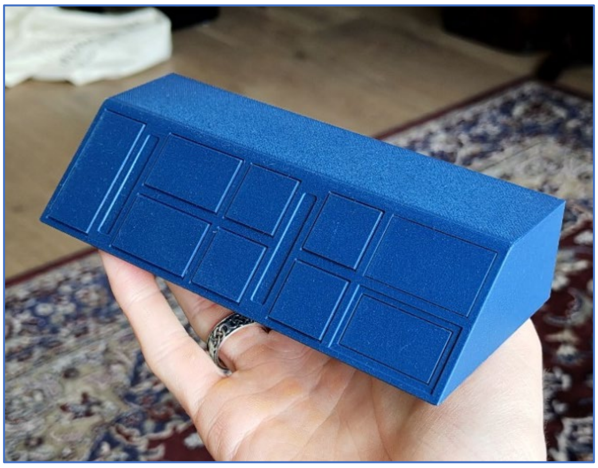


Figure 8-99: Table Swivel motion





The unit is controlled by this interface, showing above left picture. I would like you to now go through the use scenario as it would be done by the ophthalmologist with this prototype (picture on the right).

[I use the prototype without icons on the buttons. This is as, with the icons there it is much easier to simply guess at their functions]

You, the ophthalmologist, start by setting the table to the correct height. You want to increase the height.
Question 1: Where do you read what height the table is currently at?
Question 2: Now how would you increase the table height.

The patient now comes in and takes a seat in the patient chair. You want adjust their position so that they will fit behind the table better.
Question 3: How would you move the patient chair backwards?
Question 4: How would you move the patient chair up?

The patient is now in the right position, you now want to engage the table. This means making the table swivel from forwards, to sideways, so that you can start the examination.
Question 5: How would you engage the table?
Question 6: How would you switch from sitting to standing mode?

You are now done with the examination, you want to allow the patient to get out of the chair.
Question 7: How would you disengage the table?

[Now I show the interface with icons]
Question 8: Now look at icons. Do they change your answers?

Appendix 23.2 : Transcript 1

Question 1: Where do you read what height the table is currently at?
1,04, it's the only thing that's on the screen [correct]

Question 2: Now how would you increase the table height.
The button besides the screen [correct]. Makes sense that they're grouped
And then the bottom one is for down [also correct]

Figure 8-100: Respondent identifying eyepiece height

Figure 8-101: Respondent expecting functions to be the other way around

Question 3: How would you move the patient chair backwards?
[Pressed the patient chair up button, incorrectly]

Question 4: How would you move the patient chair up?
[Pressed the patient forward button, incorrectly]

Why is that?

Because they're the same size and shape as the table up and down buttons. So if that button moves the table up, it makes sense that the same size and shape button moves the chair up.

Aesthetically, I'm also not sure that I like that, coming from the right, it's long, short, short, long size buttons. But now that I think about it, I actually think chair back and forth should be on the right like you say.

Why is that?

I'm thinking y then x, like in a formula. Chair depth feels like x and height feels like y. And in formulas you first have y, then x. Like y = 2x. so in that sense height should be first, on the left. But now maybe I'm thinking too much about this.

Question 5: How would you engage the table?
[presses engage button correctly]

Why?

You might not like this, but because the other thing that's left [the mode switch button] didn't look like a button. It's recessed so I was unsure if it was a button like the other ones.

Question 6: How would you switch from sitting to standing mode?
Yeah so the recessed one. Because it's the last one that's left. But also because it's next to the screen that has the little mode icons on it. But it makes more sense to me to put the engage button with the tables adjusters, as it mainly controls the table.

The engage actually also feels like a stop button, because its double height. Like in big machines, the biggest button is the stop button, it feels like a kill switch. Which in one sense it actually is, it does disengage the thing.

But I would like it more if the icons weren't on the screen. Like now the screen is the indicator, but the control for it is not the screen, it's the button under the screen. They're split. It would make more sense to me that there would be two buttons you push, or like a switch. And no icons on the screen. Or have a touch screen where you actually push the icons. Or even have the other height and depth buttons also be switches.

Question 7: How would you disengage the table?
Makes sense that it's the same as the engage button

I also feel like it would be more intuitive to have the whole thing be a touch screen.

But it's probably easier to misuse the touch screen, as in bonk into it unintentionally

Question 8: Now look at icons. Do they change your answers?
Yeah it's still weird to me that the table and chair up & down buttons are different sizes.

The design also feels old timey, like an early Windows interface.

Why is that? What would be more modern to you?

Maybe by making the whole thing a screen, and not so grey. By not just having straight grey boxes. Also the icons are too similar, and there are too many icons. You could just depict 1 table with 2 buttons around it, and 1 chair with 4 buttons around it.

Also now that I think again actually, as the icons are above each other I would also go for the buttons that are above each other, on the left of it, to change the mode.

I also don't love that there's a square icon on the rectangular engage button

Most importantly: Shape consistency is off, 6 drawings for 2 moving things seems unnecessary, I don't know if the recess is really necessary.

And to press the button and have to move out of the way? That seems impractical

Appendix 23.3 : Transcript 2

Question 1: Where do you read what height the table is currently at?
(Points at the screen) [correct]
That seems obvious

Question 2: Now how would you increase the table height.
(Correctly pushes the table up button)
And then the bottom button to bring it down

Question 3: How would you move the patient chair backwards?
(clicks the patient-up button, incorrectly)

Question 4: How would you move the patient chair up?
(clicks the patient-forward button, incorrectly)

Why did you choose that button?

Because the other two on the right are to bring the table up and down, so these other two buttons are the same size and position, so I think they also control height but of the patient chair. That way the functions and design are the same.

And I can clearly see that the long indentations are separations between the table settings and the chair settings.

Question 5: How would you engage the table?
(clicks the mode switch button under the screen, incorrectly)
Because I only need one button for that, so it's the separate single button. And the table engage/disengage is the only functionality that isn't really a setting, but rather an on/off button. It then makes sense that that is the only button that looks different, hence it being recessed, unlike all the others.

Question 6: How would you switch from sitting to standing mode?
(clicks the engage button on the left, incorrectly)
I click that one because it's what you do when everything is set. All the settings are done, and then you set the mode. So I feel like you would do that last, so its on the left. Which is the closest to where you end up when you're examining the patient.

Question 7: How would you disengage the table?
Press that engage button again

Question 8: Now look at icons. Do they change your answers?
Yes now that I see the sitting/standing icons on the screen match the icons on the button under it that seems to make sense.

I do think it makes more sense to have the button to move the patient backwords on top, and the one to move them forwards at the bottom. It's like a traffic sign, where forward, or away from you is an arrow upwards. Which is different to how it's laid out right now.

The 'on button' to bring your table in seems to make sense with that icon. It looks a bit like an on/off symbol.

And I think it makes sense to have the most used buttons be close to you, so on left, which seems like it's already the case.

And I really like those sections. So that the long indentations indicate the split between table settings and chair settings.

The last thing I would say, is that as it is currently, the chair icons, and the sitting/standing icons face the same way, to the right. That seems to indicate that the sitting/standing figures are the patient, getting out of the chair, instead of the ophthalmologist, which they are supposed to indicate. If you mirror one of the two, it would make it clearer.

Appendix 23.4 : Transcript 3

Question 1: Where do you read what height the table is currently at?
(Points at the screen) [correct]

Question 2: Now how would you increase the table height.
I'm not entirely sure but I think the very left button. As I am setting the height of the table, I feel like that would also be a long button, and this is the only long button. So it would pivot down and up like a volume button on the side of a phone to bring the table up and down.

Question 3: How would you move the patient chair backwards?
Well for one, the long indentations seem to indicate some sort of grouping, but I'm unsure what they group.

I really like that it's a physical button panel though, and not a touchscreen. If it's possible to do physical buttons I think that's always better. With a touchscreen you're more prone to bump into it unintentionally, and with physical panels you have more freedom with depth and thickness etc.

Question 4: How would you move the patient chair up?
(clicks the chair-forward button, incorrectly)
Because it's up and down, so I need two buttons?

And what made you choose those two, as opposed to the other stacked buttons?

I'm not really sure.

Question 5: How would you engage the table?
(clicks the chair-up button, incorrectly)
I would engage it with that broad top button, as because it's broad, it seems to have something to do with that broad rotating motion.

Question 6: How would you switch from sitting to standing mode?
(clicks the mode-switch button, correctly)
Because it's under the screen, that seems to indicate the sitting or standing mode with the little icons. So then it feels like the button under the screen is connected to those icons.

Question 7: How would you disengage the table?
Disengage and engage are probably done with the same button.

Question 8: Now look at icons. Do they change your answers?
What I wonder is, why are the patient up/down buttons a different size to the others? It would make more sense, as they also do height, that they're the same size as the table up/down buttons.

I would also expect that the back and forth buttons, as they really do the same, just the other direction, would be more connected. Like a solid volume button or joined against each other.

I do like that the mode switch button is so different, and less accessible in a way, because when sending the patient up so far, you do want to be sure of yourself when you use it.

Maybe make the up/down, back/forth buttons more connected, like if they meet. As you have with phone volume buttons, where you can really slide your finger between the two buttons.

Appendix 23.5 : Results

This paragraph contains the results from the third user test.

1. Respondents understand the relatedness of the vertical button pairs, but their function bindings cause confusion. Most notably, all respondents mentioned that height adjustment keys for chair and table should be similar to communicate their similar functions.
2. Respondents understand the vertical indentations' meaning as functionality groupings, but they do not always clearly understand what they group.
3. Respondents can clearly see that the indented bottom right button (mode switch) is distinct from the rest of the buttons, and they also agree that the mode switch button should be distinct from the rest, but the function and button are not always connected right away.
4. Respondents mention that more differentiated button shapes and positioning could increase insightfulness of the panel
5. Respondents get confused by the chair icons and sitting/standing ophthalmologist icons on the panel. For one they are unsure to what buttons these screen icons relate. Secondly, the fact that they face the same direction is said to communicate that they are the same, as opposed to the intended distinct opposites.

6. It is unilaterally understood that engage and disengage are embodied in the same button.

Appendix 23.6 : Conclusions

Concluding from this test, the current panel does not provide enough guidance with its form and layout, to instantly tell the user its functions.

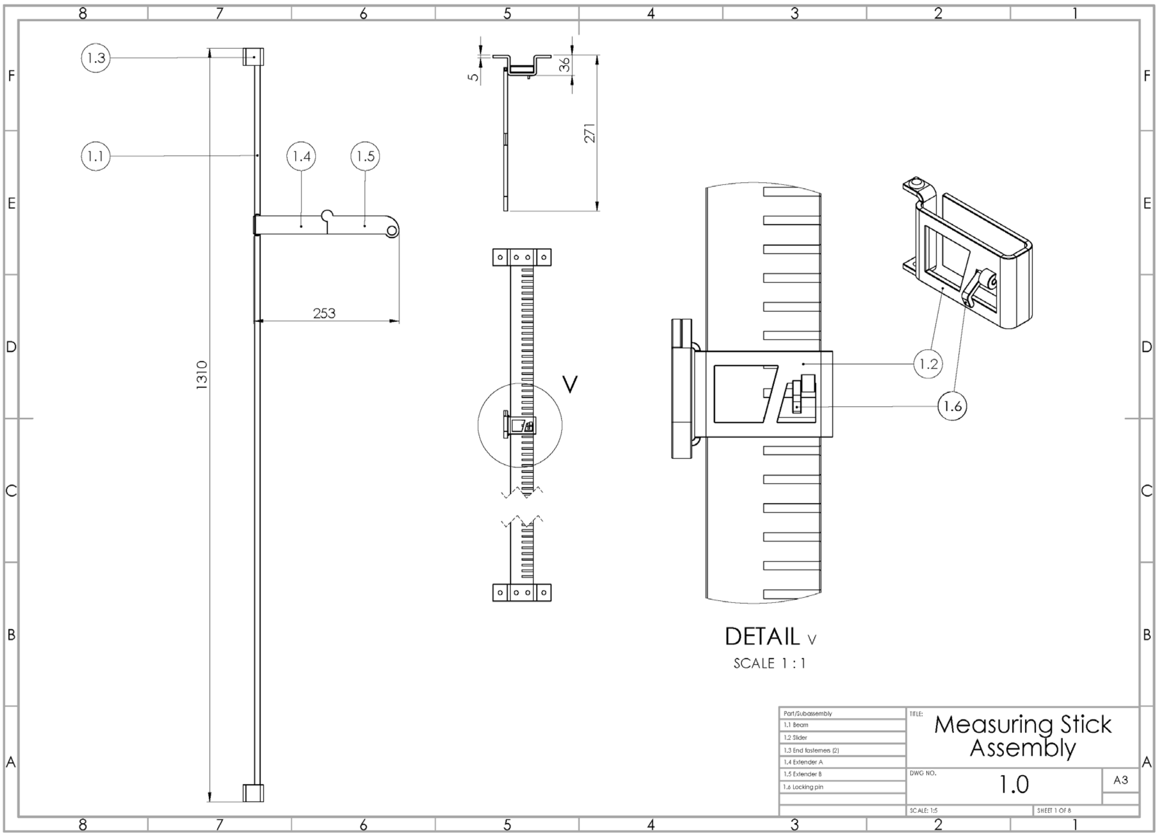
Several clear design guidelines can be distilled:

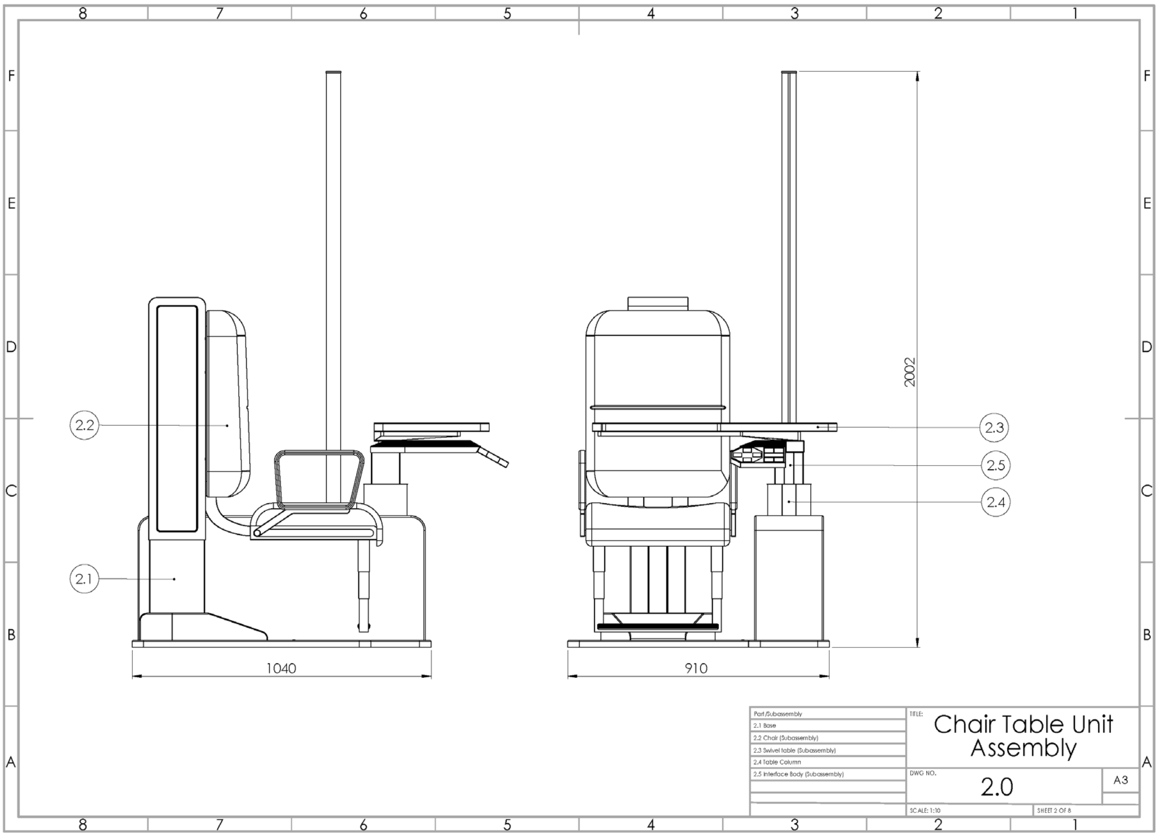
1. The button pairs that control up/down and back/forth should be more connected, either visually or physically, to show their relatedness.
2. The table height and chair height buttons should look more similar in terms of shape, size and positioning to indicate that they both control heights.
3. The chair icons and sitting/standing ophthalmologist icons should be facing each other, as opposed to in the same direction. This communicates that they are not related, but actually distinct opposites.
4. The vertical indentations clearly indicate functionality groupings, but it is not always clear enough what they group.
5. Engage and disengage should indeed be the same button.
6. Respondents can clearly see that the indented bottom right button (mode switch) is distinct from the rest of the buttons, and they also agree that the mode switch button should be distinct from the rest, but the function and button are not always connected right away.
7. The panel's appearance left things to be desired.

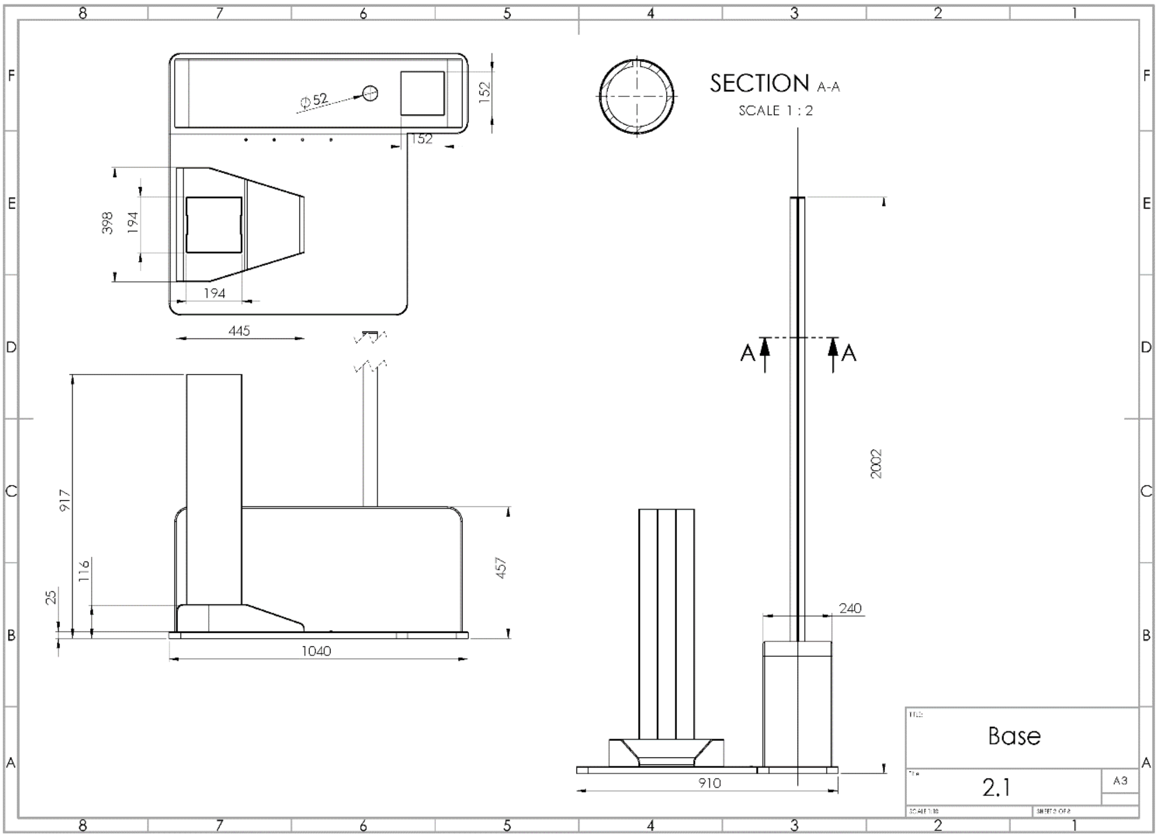
Using these guidelines, I designed the final interface that is presented in this report.

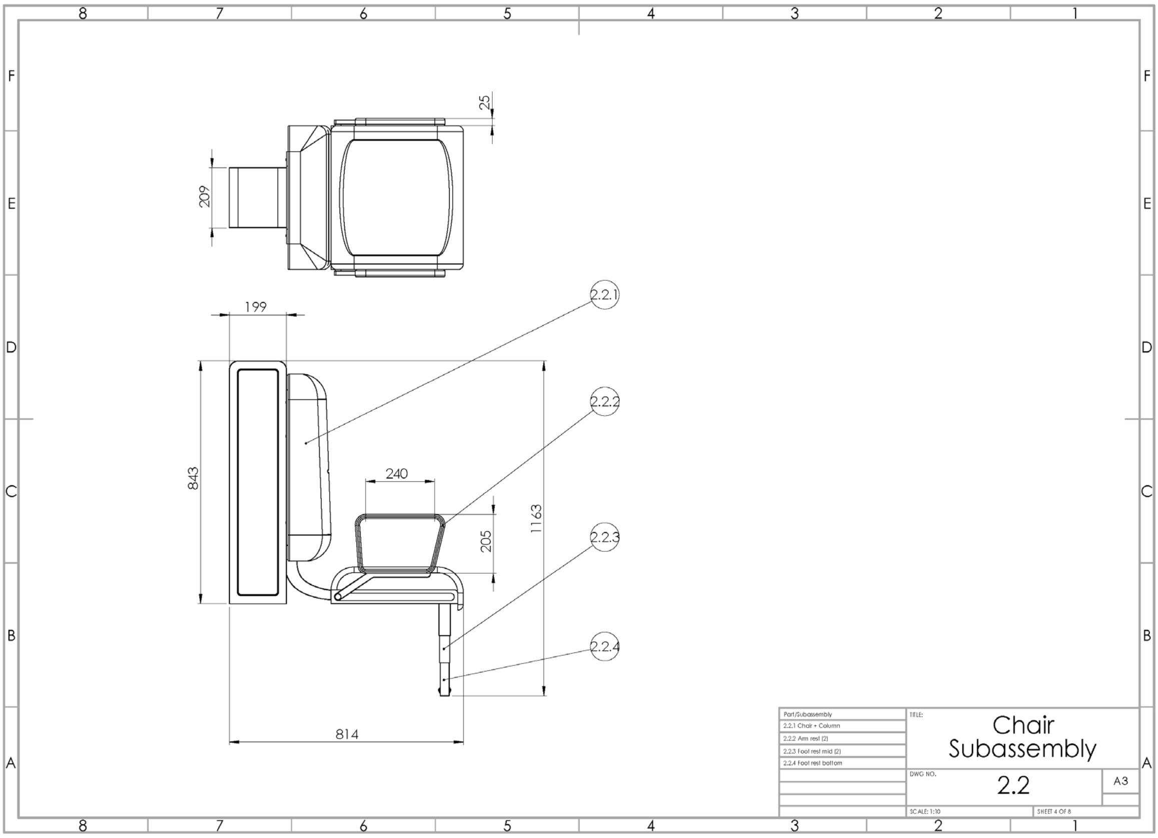
Appendix 24 : Technical Drawings

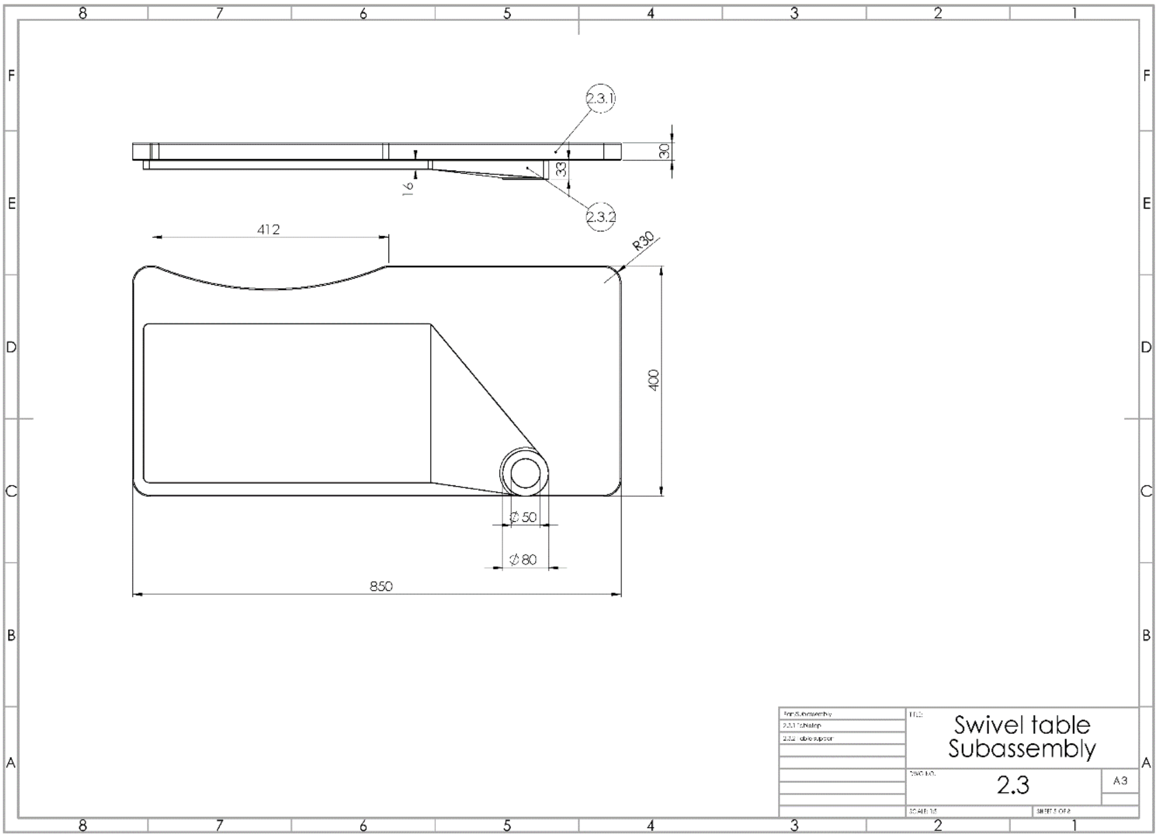
This appendix includes the technical drawings for the main parts of the concept, measuring stick, chair/table unit, and interface, respectively.

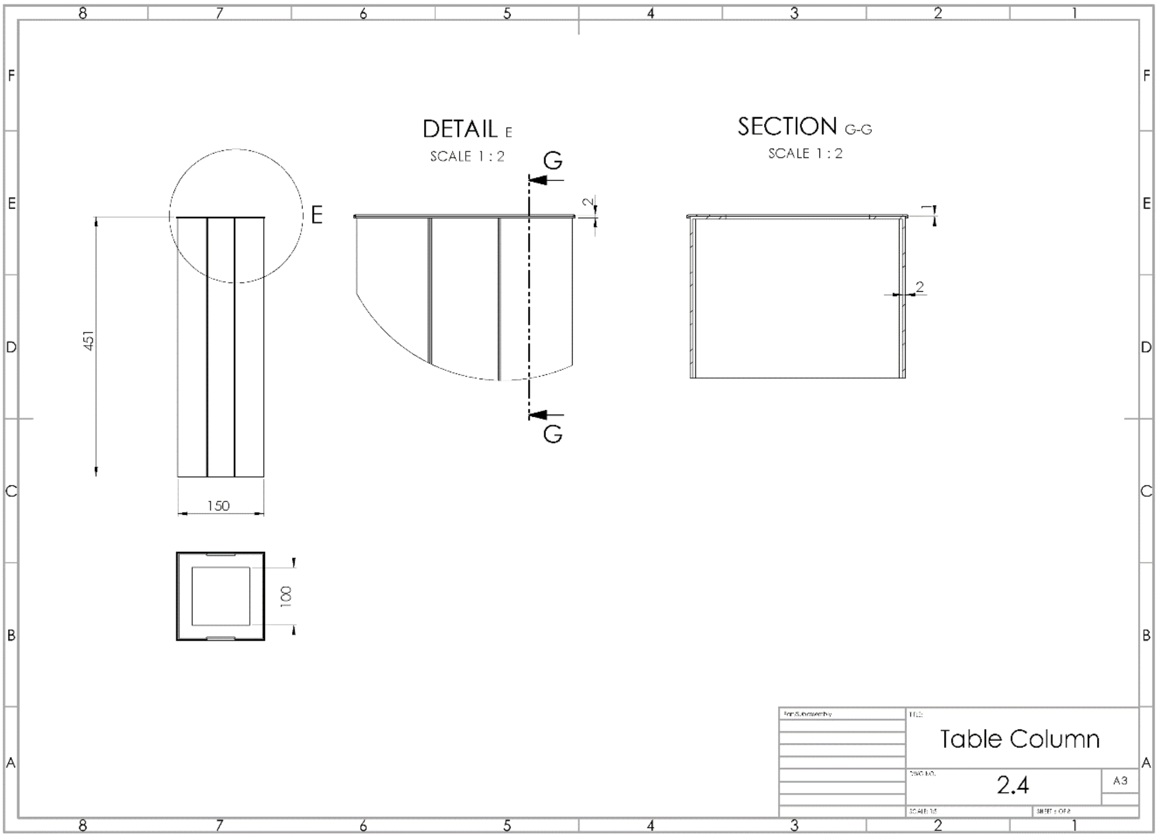


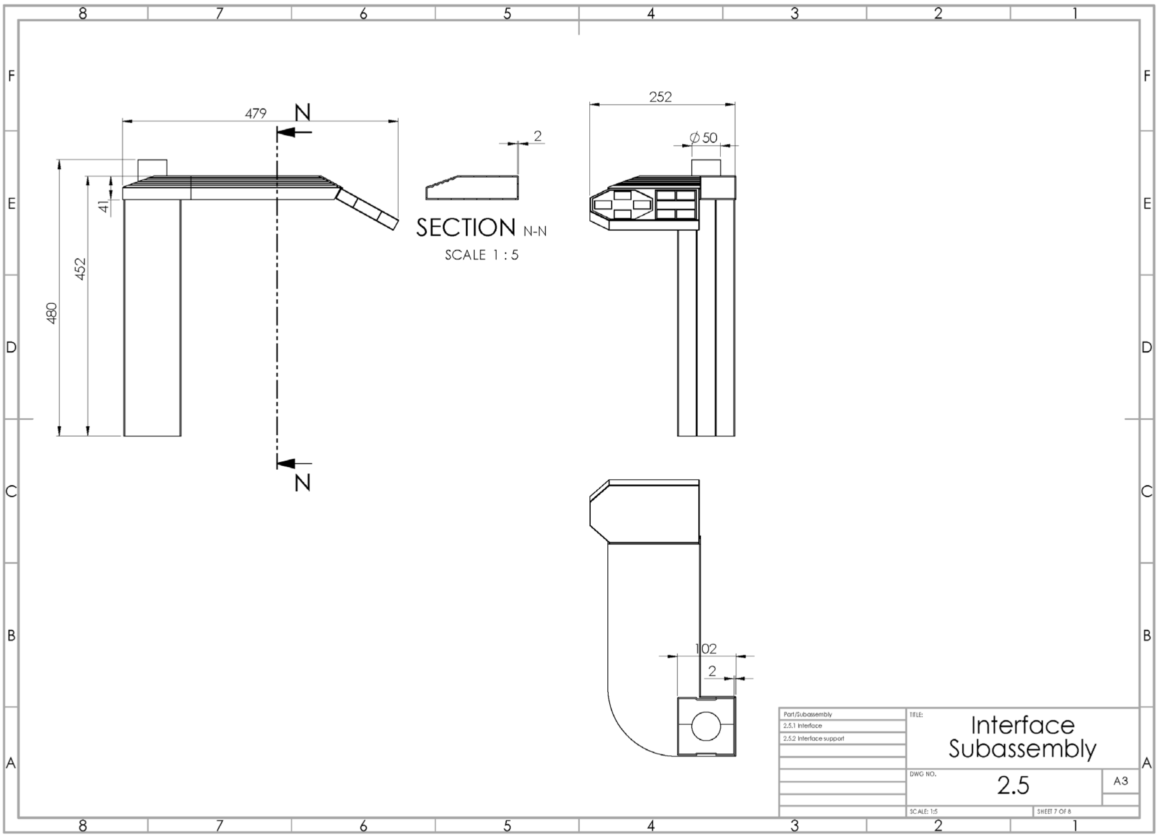


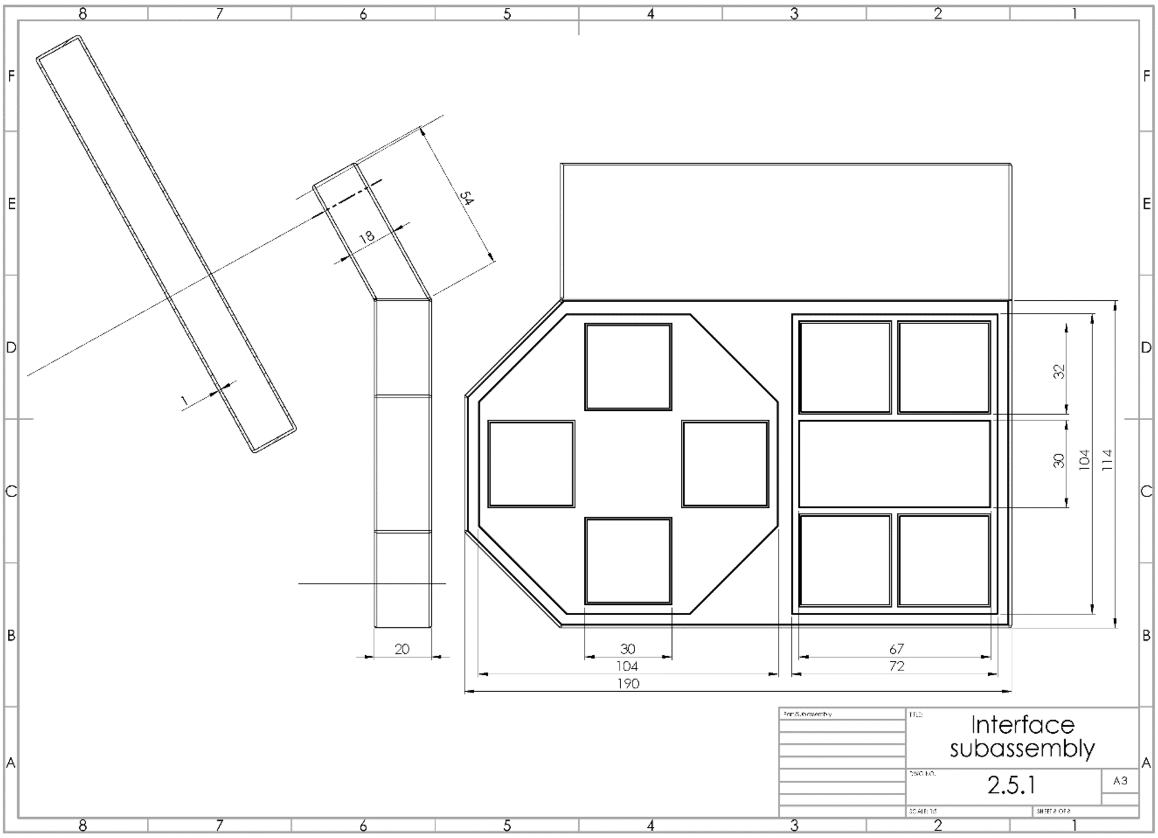

SECTION A-A
SCALE 1 : 2
⌀52
152
152
398
194
194
445
917
116
25
457
1040
2002
240
910
A
A
Base
2.1
A3


25
209
199
843
240
205
1163
814
2.2.1
2.2.2
2.2.3
2.2.4
Part/Subassembly
2.2.1 Chair + Column
2.2.2 Arm rest (2)
2.2.3 Foot rest mid (2)
2.2.4 Foot rest bottom
TITLE:
Chair
Subassembly
DWG NO.
2.2
A3
SCALE: 1:10
SHEET 4 OF 8


2.3.1
30
33
16
2.3.2
412
R30
400
⌀50
⌀80
850
Swivel table
Subassembly
2.3
A3


DETAIL E
SCALE 1 : 2
SECTION G-G
SCALE 1 : 2
G
E
2
1
2
451
150
100
G
Table Column
2.4
A3


479
N
480
452
41
SECTION N-N
SCALE 1 : 5
2
252
⌀ 50
102
2
Interface
Subassembly
2.5
A3


54
18
1
20
30
104
190
67
72
32
30
104
114
Interface
subassembly
2.5.1
A3

Appendix 25 : Glossary

This appendix includes a list of ophthalmic and medical jargon used throughout this report.

- Burnout
    - As explained by World Health Organization: WHO (2019): '*Burn-out is a syndrome conceptualized as resulting from chronic workplace stress that has not been successfully managed. It is characterized by three dimensions: feelings of energy depletion or exhaustion; increased mental distance from one's job, or feelings of negativism or cynicism related to one's job; and reduced professional efficacy.'*
- ENT doctor (Ear Nose Throat doctor)
    - As explained by American Medical Association (n.d.): '*An otolaryngologist-head and neck surgeon provides medical and/ or surgical therapy for the prevention of diseases, allergies, neoplasms, deformities, disorders, and/or injuries of the ears, nose, sinuses, throat, respiratory, and upper alimentary systems, face, jaws, and the other head and neck systems.*'
- Independent treatment centre (ZBC, Dutch abbr.)
    - ZBC's are private healthcare institutions and a often a partnership between 2 or more medical specialists (Ministerie van Algemene Zaken, 2023). As explained by Patiëntenfederatie (n.d.): '*they are commercial institution and are not subsidized by the government. They are often specializes in a particular treatment […] ophthalmology […]. This means that it has a more limited offering than a hospital, but can therefore often provide more efficient care. ZBCs are also called independent clinics or private clinics.'* They are characterised by planned care, as opposed to the generally more immediate and acute nature of care in hospitals.
- Indirect ophthalmoscope
    - As explained by Cordero (2017): the '*indirect ophthalmoscope, is an optical instrument […] that is used to inspect the fundus or back of the eye. It produces an stereoscopic image with between 2x and 5x magnification. It is valuable for diagnosis and treatment of retinal tears, holes, and detachments. The pupils must be fully dilated for it to work well.*'
    - Fethke et al. (2015) furthermore concludes that the Indirect ophthalmoscope is highly strenuous to use: '*Results indicated that while computer use was the most frequently performed clinical activity, use of the indirect ophthalmoscope, followed by use of the slit lamp biomicroscope, required greater muscular demands than computer use or other clinical activities. Results provide evidence that the clinical activities of indirect ophthalmoscope and slit lamp biomicroscope use are appropriate for ergonomic intervention.'*
- Musculoskeletal Injuries (MSI's)
    - As described by the World Health Organization: WHO, (2022), Musculoskeletal Injuries '*comprise more than 150 different diseases/conditions that affect the system and are characterized by impairments in the muscles, bones, joints and adjacent connective tissues leading to temporary or lifelong limitations in functioning and participation. Musculoskeletal conditions are typically characterized by pain (often persistent) and limitations in mobility and dexterity, reducing people's ability to work and participate in society. Pain experienced in musculoskeletal structures is the most common form of non-cancer pain.*'
- Ophthalmologist

  - Ophthalmologists have the highest level of specialisation training and differ from the other eye-related medical professions in what they can diagnose/treat (Hull, n.d.) (Lentiamo.nl, 2024). An ophthalmologist is a medical doctor whom diagnoses eye diseases, prescribes treatment including glasses and performs surgery. They are also the only eye-related medical profession that can prescribe medication.
- Ophthalmology Standard Practice (‘*Oogheelkunde Normpraktijk*’)
  - A respected advice document, published by NOG, and revised every several years containing norms and descriptions of the ideal working conditions for Dutch ophthalmology practices. This includes specifications like room sizes, expected activities of ophthalmologists and support staff, and equipment lists.
- Opticians
  - are trained technicians, not qualified to diagnose or prescribe, but instead focussed on the fitting of glasses. They generally do not work in a medical setting.
- Optometrists
  - Optometrists also perform a number of treatments. After identifying eye conditions, the optometrist refers the client to the GP or ophthalmologist if necessary. Upon referral from the general practitioner or ophthalmologist, the optometrist carries out follow-up examinations regarding eye disorders (OVN, n.d.). They examine the eyes for possible abnormalities. In the case of detected refractive errors, the optometrist advises on necessary optical correction or aids, such as glasses and contact lenses, to eliminate, reduce or compensate for the error.
- Otolaryngologist
  - See ENT Doctor
- Phoropter
  - A phoropter is used by eye care professionals to determine a patient’s prescription for corrective lenses.
  - As described by Kie (2024): ‘*The phoropter device is one of several refractors or optical telescopes. It enables ophthalmologists and optometrists to determine vision issues. For example, it can help diagnose near-sightedness, far-sightedness, astigmatism, and presbyopia.*’
- Physician assistants (PA’s)
  - Physician assistants are, in terms of qualifications and skills, between an ophthalmologist and an optometrist. The PA may prescribe a number of medications and perform low-complexity, common routine procedures.
- Repetitive Strain Injury (RSI):
  - As described by Healthline (Hecht, 2017): ‘*A repetitive strain injury (RSI), sometimes referred to as repetitive stress injury, is a gradual buildup of damage to muscles, tendons, and nerves from repetitive motions. RSIs are common and may be caused by many different types of activities, including: using a computer mouse, typing, swiping items at a supermarket checkout, grasping tools, working on an assembly line, training for sports’*
- Ophthalmic residents
  - Residents are ophthalmologists in training, but who are receiving and diagnosing patients under the supervision of a fully certified ophthalmologist.
- Slit lamp

   - The slit lamp is the main piece of examination equipment used by ophthalmologists. It allows the doctor to look into/onto the patient's eye with an array of magnifications.
   - As explained by Kaur (2023): '*A slit lamp is the most common ophthalmic equipment used by ophthalmologists in daily clinical practice. It is an essential instrument in the ophthalmologist armamentarium. Slit lamp not only provides a magnified view of intraocular structures (anterior and posterior segment) but also help in qualitative and quantitative analysis of various parameters such as corneal endothelial cell count, corneal thickness, anterior chamber cells, and flare assessment, depth of anterior chamber, pupil size, grading of cataract, slit lamp photography, etc.*'
   - Fethke et al. (2015) furthermore concludes that the slit lamp is highly strenuous to use: '*Results indicated that while computer use was the most frequently performed clinical activity, use of the indirect ophthalmoscope, followed by use of the slit lamp biomicroscope, required greater muscular demands than computer use or other clinical activities. Results provide evidence that the clinical activities of indirect ophthalmoscope and slit lamp biomicroscope use are appropriate for ergonomic intervention.*'
   - For more information and imagery, see Ophthalmological Clinic Analysis: Slit Lamp, Table & Patient chair
- Technical ophthalmic assistants
   - Technical ophthalmic assistants are technical supporting staff in the medical setting. They carry out some of the examinations on behalf of ophthalmologists. They work on the instructions of an ophthalmologist.
- University Medical Centre (UMC)
   - University Medical Centres are health care institutions that are connected to a university. As described by NFU (n.d.): '*In addition to their hospital function, the UMCs have three other public tasks: caring for top referral patients* [referring to people for whom standard treatment is not possible, because of the complexity of their ailment]*, conducting scientific research and training the healthcare professionals of the future. The embedding of science and training in the most complex care distinguishes UMCs from top clinical and general hospitals.*' UMC's are therefore defined by their educative role, as well as the complexity of care they can provide.
- Work-related Musculoskeletal Injuries (WMI's):
   - See Musculoskeletal Injuries (MSI's)