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Intuitive UX In a Redesign of Ullmanstolen

Master's thesis in Industrial Design Engineering

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Exploring Intuitive UX in a Redesign of Ullmanstolen
Usability of an office chair adapted to a modern working environment
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Cover: The image depicts the redesigned Ullmanstolen chair from three angles, showing the controls on the chair as well as the full chair. Printed at Chalmers Digitaltryck.
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Abstract

Office work has gone through changes in the past decades, with office chairs adapting, adding more controls to provide better ergonomic support. But more adjustments have resulted in a lack of understanding of how to correctly use chairs, which can negate the intended benefits and harm the user's posture. This master thesis aims to improve usability of the controls, based on an investigation of users' current understanding of the settings and drawing conclusions on how this can guide the design of the controls. The chair this research focuses on, Ullmanstolen, was launched around forty years ago and therefore provides a good starting point for adapting to new types of working environments. A design guide is established through a user study and user evaluation. To address the lack of understanding of adjustable chair settings, a design of clearly visible, distinct controls adhering to placement conventions and user's mental models is vital, showcased in a redesign of Ullmanstolen.

Keywords: user experience, intuitive design, office chair controls, control mapping.

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Glossary

Ullmanstolen	Swedish for ‘The Ullman chair’, to be used interchangeably. Throughout the report ‘the chair’, if not specified further, refers to Ullmanstolen.
Office chair, task chair	A chair typically used at a work desk, with controls that allow adaptation to different body sizes and postures; ‘chair’ in the thesis will refer to this type of chair
Shared office, flexible office	Similar to activity-based workspaces, shared or flexible offices are typically open-plan, without individually assigned workstations and freedom to switch workplace based on day or activity (Wohlers & Hertel, 2016).
Intuitive	“Easy to use or learn without any special knowledge” (Cambridge Dictionary, 2019)
Definition of the controls	
Seat height	The distance between the seat and the floor, to be raised and lowered for optimal leg and back support.
Seat/Backrest position	The distance between the back edge of the seat and the backrest, determining how much space users have to sit on the chair.
Tension	The resistance a user encounters when leaning against the backrest before the backrest tilts backwards or forwards.
Tilt lock	A mechanism that locks the backrest in one place, blocking the back/forward tilt of it.
Armrest height	The distance between the top of the armrest and the seat, to be raised and lowered for the best arm placement.
Armrest position	The placement of the armrests in relation to the seat and backrest, referring to both the width the armrests are apart and the closeness to the backrest.
Neckrest/ Headrest position	The position of the neck pillow can be changed in 2 directions usually, moving up and down in height and back and forth towards the users’ head. Some can also be rotated up and down along one axis.
Backrest height	The backrest can be shifted up and down to adapt the curve of the seat to the position of the users’ spine.
Resting tilt/ Backrest angle	The angle at which the backrest is positioned in a resting state, tilting either towards or away from the user.
Lumbar support	A curving of the backrest towards the user in the lower back region, intended as extra support.

1. Introduction

This section presents the background for the thesis, aim and research questions to be answered. The thesis work was carried out in a team of two, with Sanna Dahlman as supervisor and examiner from Chalmers and the company EU Ergonomiutveckling AB in collaboration with the chair's creators, Johan and Pia Ullman.

1.1. Background

Office chairs, or office task chairs, have developed more complex settings to adapt to the human body, but the understanding of how to use these controls is often lacking. A lot of research has been done into adapting a chair for the correct sitting position to prevent bad posture and backaches and improve comfort (Mandal, 1981) but studies have shown that few office workers are aware of or use the functions available to them, possibly due to a lack of understanding of the controls (Underwood & Sims, 2019; Vink et al., 2007). This thesis was conducted on an ergonomic office chair 'Ullmanstolen'. The Ullman chair was designed to support a better posture when sitting for long hours at the office when it was first released in 1986. It was a product known in Sweden at the time for its unique design with a lot of potential to provide value to users due to its strong technical and ergonomic basis (P. Ullman, personal communication, n.a.). However, the controls to set the correct ergonomic position are hard to find and use, leading to a bad posture. The project group proposed to adapt the product to the current market for office task chairs, whose users' needs and expectations are going to be the basis for a redesign of the product. With purchasing behaviour moving more to online sales, as exemplified by growing furniture e-commerce (Statista, 2023), personal instruction is becoming less frequent, though it was found to strongly improve user understanding on how to correctly use an office chair (Osvalder & Colmsjö, 2015). To facilitate better posture and use Ullmanstolen should become more intuitive and easier to set to each person's needs by using the controls. The chair will be explored regarding form language and materials on how it reflects current market needs to be competitive by showing its unique features, such as the many use settings. The model of the Ullmanstolen chair range considered throughout this body of work is the 'Q-lite'.



Figure 1, The original Ullmanstolen range, from the short 'Slim' to the high-backed 'NiteFlite'. Promotional material of Ullmanstolen.

1.2. Aim

The aim for the thesis was to research and evaluate the user experience of Ullmanstolen with a focus on intuitive controls. The goal is to provide a seamless setup experience which enables comfortable sitting in daily office work. The chair's design is analysed with regards to its appeal to modern audiences and its perceived value as an ergonomic office chair.

The research questions to answer are:

- What shapes a user's understanding of the controls of Ullmanstolen and other chairs?
 - How can this guide the design of the controls to be more intuitive?
- How can Ullmanstolen's unique features be emphasised while appealing to current user preferences?

Deliverables

The deliverables for this thesis are

1. A concept for a Ullman chair design with improved usability
2. A set of design guidelines for improving usability in office chair controls

1.3. Demarcations

The project took place during the spring of 2024, between the 15th of January and 5th of June. The project will focus on the conceptual and prototyping level, and not the details of manufacturing.

The ergonomic decisions the chair was designed around will not be questioned or changed throughout this research and are therefore out of scope. There is a range of models of the chair of different heights and use cases. This thesis focuses on one model only, the Q-lite, but the results may be transferable to the other models to an extent.

1.4. Structure of the Project

The structure of the project is based on the iterative nature of the double diamond method (*The Double Diamond - Design Council, 2024*) where the research phase explores the problem, broadening out before defining the scope and providing a basis for defining the needs for the project. The next broadening out occurs by ideating in the solution space, before creating a prototype to validate and narrow down the solutions. An adaptation to the double diamond method was made to fit the scope for the project (see Figure 2).

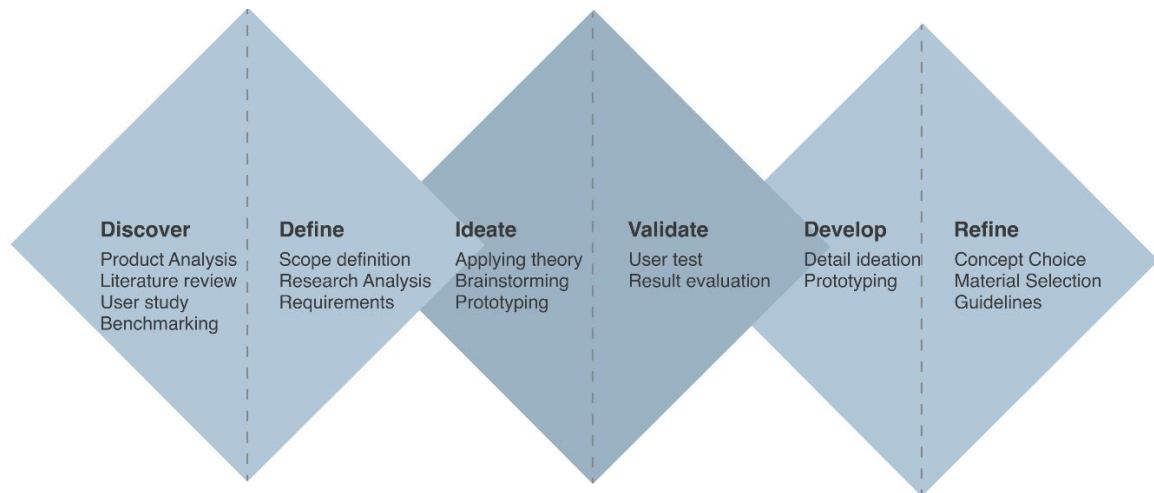


Figure 2, Overview of the process

Starting out in the discovery phase with the research questions, academic research and a market benchmarking as well as user studies are conducted. This creates a knowledge base for pinpointing the necessary aspects for a redesign. The insights of the literature review and user study are the first narrowing, defining the problem. Out of this follows an iterative cycle of ideation and prototyping with user testing of the prototypes before refining the tested designs further in a second prototyping cycle. The second narrowing occurs with the prototyping results guiding further designs. The project use of the double diamond method adds extra iterative cycles of exploring a more detailed solution space and another round of prototyping, leading to a final design and prototype, narrowing the diamond for a third time.

2. Theoretical Framework

This section presents a literature study that forms the basis for conducting user studies and creating the redesign of the Ullman chair's controls. It analyses user knowledge and understanding of office chairs and controls. It will also investigate existing design principles regarding usability and how those relate to the design of controls.

2.1. Office Chairs

The first part of the theoretical framework centres research on office chairs, including how they are used, how frequently the chairs are adapted using controls and the level of understanding users have of these controls, which leads into aspects shaping this understanding.

2.1.1. Shared offices

Work in shared offices has been increasing (Statista, 2023), meaning that office chairs are used by different people each day. This limits the time and effort that people will exert in 'getting-to-know' the chairs while at the same time requiring daily adjustment to fit the individual sitting in the chair. To ensure proper ergonomic use, it is recommended that the employees are instructed about the chair by the company, and how to achieve a good posture using the different settings. With time and resource limitations, instructing all employees becomes impossible and leaves calibrating an office chair to the individual, resulting in incorrect sitting. Intuitive controls are therefore a prerequisite for office chairs being used correctly as their features are often complex and not used by all even when it is recommended (Osvalder et al., 2013), which leads people to sit incorrectly and posture problems in the long run (Mandal, 1981).

2.1.2. User knowledge

With active sitting being encouraged for health reasons, such as increasing blood flow for improved circulation (Mandal, 1981), it is desirable for users to adjust their office chair more frequently, to lock and unlock the tilt of the backrest for example (Osvalder & Colmsjö, 2015). However, more than half of users in one study by Vink et al. (2007) were found to never adjust their office chair. The reasons for lack of adjustment are not clearly known (Groenesteijn et al., 2009) but a study conducted by Underwood & Sims (2019) showed that not understanding how to make the necessary adjustments had the strongest correlation to lack of use. Studies by Osvalder & Colmsjö (2015) and Goossens et al. (2012) also found that understanding of controls increased when instruction was given on how to use a chair, and according to Osvalder & Colmsjö (2015) the frequency with which people used the controls to change settings also increased. This points to a lack of awareness of the settings' existence and their use as a reason for why users do not adjust the chairs, as suggested by Underwood & Sims (2019). A study on user knowledge of controls by Hedge (2016) across 1000 office workers in North America, Europe and Asia found similar results, where most users were not aware of the controls, the seat height and armrest height control being an exception. Interestingly, the study also showed no

significant difference in knowledge of controls between users who had in the past received training on chair use and those who had not (Hedge, 2016).

The awareness of controls also differed between the chair's control type and the country of study, with knowledge of the backrest angle and resistance adjustment for Dutch participants below 30% (Vink et al., 2007). The study showed that 61% of Dutch office workers do not adjust their chairs, compared with only 24% of Spanish participants, pointing to cultural differences as a factor. This was also noted as a possible factor in understanding of controls by Underwood & Sims (2019).

2.1.3. Usability

With the large gap between availability and understanding of chair controls, simple, intuitive design becomes very important (Helander et al., 1995; Hedge, 2016). Groenesteijn et al. (2009) illustrate how changing the controls can improve the accessibility as well as the intuitiveness. They show a positive connection between the speed of finding and adjusting a control and the frequency with which it will be used. In the paper they also relate the preference of a chair's setting to the familiarity the user has with that setting (Groenesteijn et al., 2009). Apart from familiarity, the control's design and placement plays an important role in correct use. In a study by Helander et al. (1995), the use of a control is divided into search, identification and adjustment phases, with corresponding factors discernibility, feedback and compatibility determining success of use. The first two factors, being able to find the control and receiving feedback on actuation, were most defining, likely because failure in these stages prevents transition to the third phase of how well the adjustment matches expectations. The large differences in the understanding of the different controls indicate that differing placement and control types as well as what the controls communicate varies. The seat height was frequently rated as the control with the highest level of understanding, with above 70% and even up to 90% of study participants able to identify this control (Helander et al., 1995, Vink et al., 2007). In contrast, the backrest tension was identified by only between 26% and 42% (Vink et al., 2007) and less than 30% (Helander et al., 1995). In the study by Hedge (2016) across 1000 office workers, only 4,1% were able to identify the backrest tension of their chair, compared with 46% identifying the seat height.

2.2. Design Principles

This part of the theoretical framework discusses theory related to knowledge formation and its influences on design and usability, which aims to help understand how design can influence use of products.

2.2.1. Mental Models

A mental model describes the idea a user has of how a product works and how they can use it (Martel & Mavrommati, 2001). There are shared ideas between people, called 'common sense' (Martel & Mavrommati, 2001), which have to be shared by the target group of the product, in this instance the people regularly sitting in an office chair, either at an office or at home. And in the process of learning to use such a product a *system image* is built up - consisting of the

product's visual clues, instructions given and the interaction between user and product (Martel & Mavrommati, 2001; Norman, 2001). The way of communicating the use of controls, especially to first-time users is referred to as mapping (Norman, 2001). Placing the controls in a 'natural mapping', a layout most in line with the user's mental model, reduces the cognitive load on users of having to know and remember where which control is placed. This eases the use for both workers often switching chairs and those rarely using their chair's settings. Another way to ease use of controls is to employ metaphors to build on users existing knowledge. They create association between the unfamiliar product and a concept or tool already familiar to the user and thereby explain the products' use (Casakin, 2006).

2.2.2. Usability in a Design Context

The success of a design's use is influenced by many factors such as previous experience, domain knowledge and cultural background (Jordan, 2002), aspects that were reflected in the studies on user knowledge in office chairs (Vink et al., 2007; Underwood & Sims, 2019). Still, some principles of design have been established that serve to improve user experience universally. Well-known among these are Norman's Principles (2001), divided into the conceptual model, visibility, feedback, constraints, mapping, consistency and affordance.

The study on adjustability of office chairs previously mentioned bases the factors in use of chair controls (discernibility, feedback and compatibility) on Norman's design principles (Helander et al., 1995). In another model by Jordan (2002), factors influencing usability are the *guessability*, *learnability*, *experienced user performance*, *system potential* and *reusability* of a product. Where the first principle, *guessability*, determines how easy a product is to use the first time, with recurring interactions, *learnability* becomes more important. This concerns the daily use of the same office chair when controls are regularly adjusted but becomes more challenging in a flexible or changing working environment. There, design with high *guessability* takes precedence. For a product to have guessability the user must have an understanding of the product where Norman's principles for understandability and usability (2001) provides the basis for human interactions with products.

2.2.3. Semantics

Usability is to a large part also determined by the gestalt of the product. Product semantics describes the theory that products communicate meaning and context of use through their form or "the product is what it says to the user" (Krippendorff & Butter, 1984). But why is shape relevant? Applying semantic theory to controls can mean establishing indicators of use in the control's design or communicating the purpose of the product (Martel & Mavrommati, 2001 via Chakraborty, 2017). This is exemplified by the shape of a lever handle in *Design for Product Understanding* (Monö, 1997). Monö illustrates how the shape and knurling of the handle direct movement of the hand, even when the mechanism is not visible. He argues that we subconsciously determine movement by what provides a more pleasant experience, i.e. turning the handle with instead of against the knurling pattern. In this way, products can be given functions by linking their visual and material properties to goals of use (Muller, 2001, p. 292). And circling back to office chairs, users have been found to be better able to distinguish aesthetic than ergonomic factors (Helander, 2003) so using design features to signal to users can be a more effective form of communication. The study by Helander (2003) also uses aesthetics

as a signifier of comfort, mainly described in terms of softness, plushness, etc. In a study on comfort in passenger aeroplanes (Ahmadpour et al., 2014), the satisfaction aspect of comfort was measured in terms of quality (reliability of physical features), adequacy (ease of use) and (physical) accessibility, relating comfort back to usability factors. The study refers to Hekkert (2006), who argues that aesthetics is purely perceived in terms of sensory pleasure.

3. Methodology

The methodology chapter describes the setup of the project and theoretical framework, methods that were used and how they were applied to execute the work.

3.1. Literature Review

First, a literature review was conducted to map the existing research space on the use and understanding of office work seating. Research about controls, user experience and semantics were used to facilitate learning on how the design can be applied and evaluated. The questions central to the review regard what shapes a user's understanding of a control and how these aspects can be used to guide design to become more intuitive to use, specifically regarding Ullmanstolen. The areas explored are *chair adjustment in office chairs*, *user experience in product design*, *perception of (office chair) controls* and *semantic theory*. These were described in the theoretical framework.

The focus was on finding literature regarding what shapes and movements are typically associated with a certain type of control, for example pulling up a lever to increase seat height as well as standards on where certain controls are placed for the easiest manipulation and understanding of what that control will do.

3.2. Product Analysis

The Ullman chair was analysed in depth through self-observation, using it for extended amounts of time thereby testing the controls and later taking it apart to understand the mechanisms, with the goal of becoming familiar with the chair. The ethos behind its creation and design philosophy was explored through conversations with the chair's creators and researching models of sitting that were integral to the chair's original design. The section aims to answer the research question '*How can Ullmanstolen's unique features be emphasised while appealing to current user preferences*'. The background includes research into the chair's target audience, reason for the initial launch and its unique value. Further, an analysis of the individual controls is conducted, along with a function analysis describing each control's purpose and a shape analysis of the complete chair.

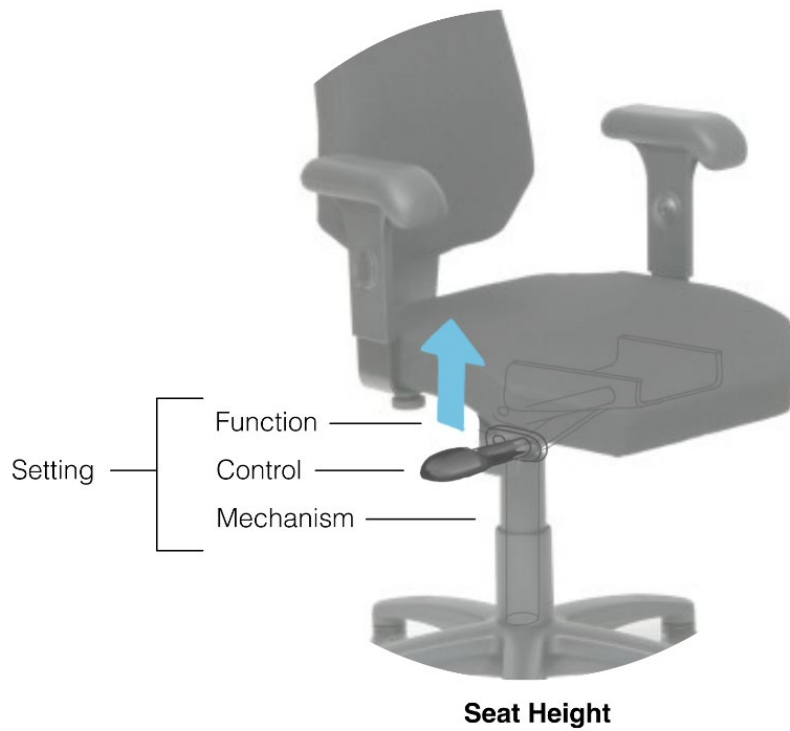


Figure 3, The conceptual levels of a seat height control as an example

There are different terms describing overlapping concepts related to how to adjust a chair to one's body. In Table 1 below, the use of the terms within this thesis are described with an example, as illustrated in Figure 3 above. When the directions are referred to in the report (e.g. the control on the left side of the seat) it is from the perspective of a person sitting in the chair.

Table 1, Terminology describing chair adjustments

	<i>Explanation</i>	<i>Example given for seat height</i>
Function	The function is a provided feature of the product	Raising/lowering the chair
Setting	The setting changes the 'mode' of the function	The 'seat height' system, consisting of both the mechanism and the interaction with it
Mechanism	The mechanism is the physical implementation of the function	The gas spring
Control	The control is the expression of the setting, and the (physical) interaction with the function	The handle for activating the gas spring

3.3. Benchmarking

A field study was conducted to gather insight on competitors and chairs with their mechanisms. This gives information on different solutions in how the controls look and are used to facilitate their usage intuitively. A range of office chair brands are evaluated through a field study at retailers, at a brand showroom and the annual international furniture fair in Stockholm. The brands analysed are listed below.

Table 2, Brands analysed (for the full list of chair models see appendix I)

- Ullman
- Malmstolen
- Vitra
- Savo
- Svenstol
- Kinnarps
- Håg
- Lanab
- Humanscale
- Tronhill
- RH
- Herman Miller
- Kenson
- Kab

Status Quo

Research on the office chair sales process was conducted at current chair retailers in Gothenburg to gather further information about common types of controls, their underlying mechanisms and the popularity of the chairs and controls. During the part of the study exploring the market, the focus was on office task chairs currently available and sold. The trends in the types of settings typically present in these chairs were analysed to find out what types of controls are used most frequently and to gauge their importance and the likelihood that these will be used. This helped to prioritise certain controls and contrast them with the controls of the Ullman chair. The study also investigated how users are instructed in the use of office chairs by interviewing the salespeople. It took place at the retailers Ergona, Nordiska Galleriet and the Kinnarps showroom.

State of the Art

The next step in benchmarking looks into the newest office chair designs. For this, designs at the Stockholm Furniture Fair 2024 were evaluated. The chairs relevant to this research, i.e. those with adjustable settings, were office task chairs and 24-hour seating. The companies at the fair whose chairs we evaluated are Humanscale, Kab, Svenstol, and Tronhill, from the USA, Sweden and Lithuania. The results of the market research are presented as a quantitative analysis of the types and number of mechanisms present across the analysed brands.

3.4. User Study

The next step was to gather further information about the Ullman chair and people's perception of it to answer the question: What do the controls communicate to the user? This was achieved using a survey and conducting interviews with observations, focusing on usability, comfort and aesthetics to gain insight into the general experience of using a task chair in two different office settings explained below.

3.4.1. Setup of the Survey

The survey was conducted with fifteen people during a three-week period with the Ullman chair, and three chairs from Kinnarps for two of the weeks as control: the Capella, 8000 and 9000 series. The chairs were placed at the Industrial Design Master Studio at Chalmers University, where people were offered to sit in one of the chairs for as long as they liked. After the testing they were asked to fill out a form (see appendix II B) that was accessed through a QR code placed on the armrest of the chair. The people participating were Industrial Design Engineering students working on their laptops at the industrial design studio which is a “flexible office”.

3.4.2. Setup of the Interviews

Interviews with observations were carried out with the Ullman chair and six people that spend a majority part of their workdays doing desk work. This was to get a better depiction of how people that sit at their own workstation for multiple hours interact with the chair. One of the interviewees was a long-term user who had been using the Ullman chair for twenty years, in two different versions and was able to give insight on other long-term users in the same office. As the people interviewed work at a desk with a keyboard, mouse and monitor, the working conditions closely resemble the position that the office chairs were designed for, as well as being a contrast to the working environment for the people filling out the survey. Before the interview, participants got to use the Ullman chair for a minimum of one working day that consisted of desk work. A semi structured interview was then conducted using the template found in appendix II and follow-up questions were asked to be able to gain further knowledge into subjects that the participants had deeper knowledge or opinions about.

3.4.3. Analysis & Evaluation

The interviews were audio recorded and later analysed using a KJ analysis. Topics were grouped into the individual controls with subcategories for understanding, comfort, ergonomics, appearance and perceived quality. Behaviour of the participants using the chair during the interview was noted and later analysed as well to support the insights. The survey results collected over the course of three weeks were analysed together with the interviews.

3.5. Establishing Requirements

The information gathered up to this point from conversations with and background given by the chair’s creators, the conducted user study and literature study was used to create a list of requirements for Ullmanstolen. In addition, a mood board was created to represent the goals for the coming design and ideation phases to act as a visual guide. The requirements address multiple topics, from usability, aesthetics to sustainability and aim to provide reference and a place to realign and confirm progress throughout the process.

3.6. Ideation and Design of Prototypes

This section describes the first ideation on paper and in clay as well as the layout for the first prototype.

3.6.1. Ideation Setup

Following the insights from the research phase, the ideation and prototyping followed in multiple iterations. In the first ideation phase, the general shape of the controls was brainstormed. This started with the type of interaction each control should enable based on the research insights and the shapes that would best facilitate that interaction intuitively. Ideas were collected throughout the research phase and noted down. To communicate and be able to evaluate these ideas and iterate on them further, brainstorming sessions were conducted for each control. A ten-minute timer was set for sketching out ideas individually. After the ten minutes, the ideas were laid out and how they work as well as the reasoning behind them was discussed. The conversation on the different ideas and preferences, whether they matched or not, enabled the next phase, which was creating clay models. Following a discussion of the sketching after the brainstorming session, clay models were created to visualise the ideas with relative sizing and testing the surface curvature. The results describe the ideated shapes and the thoughts behind the associated movements. The resulting shapes chosen from the clay modelling were modelled again with an oven-bake clay to use as prototypes in the first user test. The layout of the controls was also decided based on the insights from the previous research sections.

3.7. User Test of Prototypes

In this chapter insights from the research are evaluated through a user test of existing controls in a scenario where the placement and shape of the controls are the main focus. To test how well users understand the new control movement, and whether the designs are appropriate, a summative evaluation in the form of a usability test was conducted (Baxter et al., 2015), with assessment based on the usability section of the list of requirements outlined in chapter 4.4. The following usability requirements are assessed with this evaluation:

Table 3, Excerpt of the requirements list

Usability			
Follow a mental model	Adhere to common associations users have and employ metaphors as guides when possible.	Describe the mapping & design changes based on known principles.	2
Controls are accessible from a sitting position	Users should not need to stand up or change position significantly to find and use the controls.	Usability tests regarding shape and placement.	3
Be discoverable without looking	The user should be able to find all controls by hand only, as users typically do not look at the chair.	Usability tests regarding shape and placement.	3

Provide feedback	Provide affirmative feedback on actuation (visual, haptic, auditory).	Usability tests & motivating design decisions.	3
Give use indication	Provide reference points indicating correct use and current setting of the control.	Usability tests & motivating design decisions.	3

3.7.1. Setup and Test

The plan was to test the clay controls in an environment most closely resembling a regular office workspace, so a setup with a computer desk, mouse, keyboard and the Ullman chair was created. A pegboard was designed to be attached to the base of the Ullman chair's seat, where controls on metal rods could be placed in a variety of positions, with variable height, distance from the body and allowing some freedom for sliding and rotation when testing the controls.

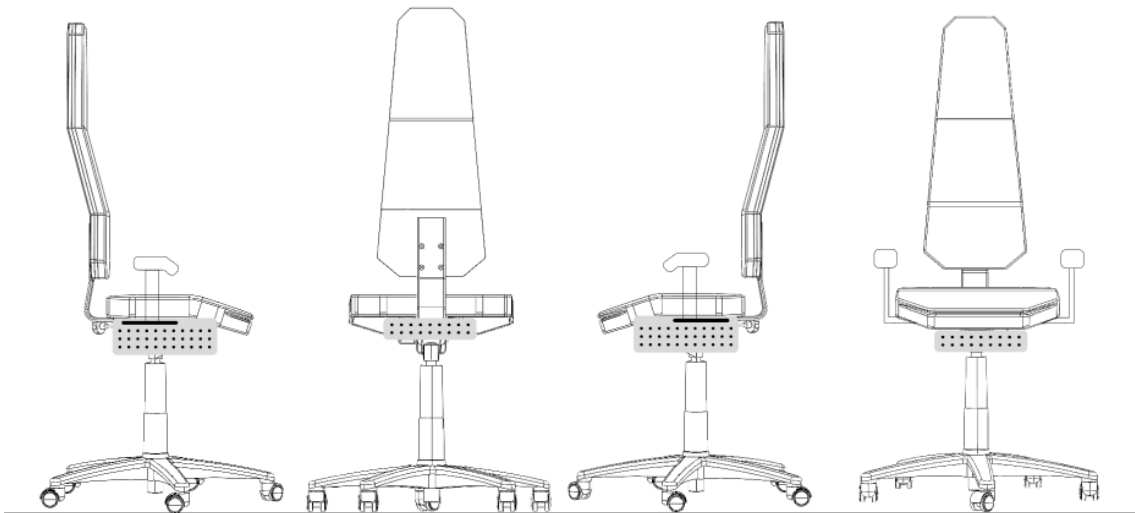


Figure 4, Illustration of the planned pegboard prototype

The initial shape and placement setup was determined in the ideation phase, based on the interview, survey and functional analysis of the Ullman chair as well as the benchmarking of the controls on the market.

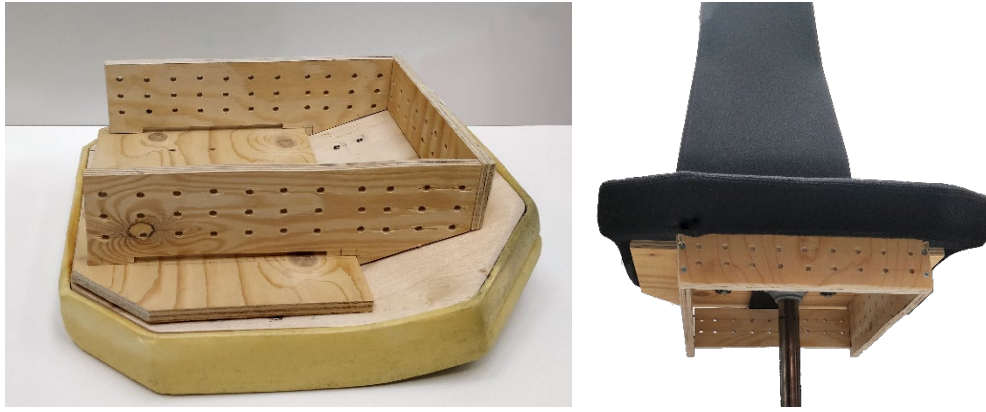


Figure 5, Prototyping the pegboard attached to the seat base

The evaluation mimicked the working conditions of an office environment. The chair was therefore placed at a desk workstation, with the chair and a table, monitor, keyboard and mouse. No other office chairs were present to minimise outside influence and comparison. A blindfold was used in parts of the test to focus on the shape of the control and avoid further understanding of what to do by visual stimuli. As the goal was for the user to adjust the chair as seamlessly as possible, it was crucial to observe the steps that the user has to take and see where the control succeeds or fails in its communication. Therefore, they were asked for consent to video- and audio-record the test for later analysis. The setup is pictured below.



Figure 6, Setup of the user test in an office environment

The procedure followed for every participant is detailed in the evaluation plan in the appendix, along with the list of participants (see Appendix D). They were asked individually to participate, asked for consent to being filmed and audio-recorded and sat down in the chair. There they were blindfolded after consent was given to that and told about the background and goal of this evaluation. They were be asked to vocalise their thoughts during the process, based on the think aloud protocol (Baxter et al., 2015, p.169). The list of controls there were to adjust on the seat was given initially and participants were then walked through them one by one and asked to share their thoughts throughout the process.

The questions were structured in the following way:

- *If you wanted to change [the height of the seat], how would you go about it and which control would you choose?*

Once they reached for one or more controls, they were asked to simulate how they would perform the adjustment action and why they reached for a specific area and made a specific motion. After each control was covered, the participants were asked to remove their blindfold and a general discussion was opened. They were asked to have a look at the controls and change out the shapes and placements and comment on what their thoughts and preferences were. The main questions were:

- *What would you change about the placement of the controls?*
- *What difficulties did you have understanding/using the controls?*

As final thoughts they were asked what other ways of changing settings on a chair they could imagine and what they thought about being blindfolded for half of the testing session.



Figure 7, Images of the participants during testing

The chair setup with control positions was noted down and changes to the positioning as well as use of the controls was noted in another image (see Figure 8). Further notes are listed in appendix III, User Test. The image describes the layout of the controls as they were on the prototype to illustrate the intended setup compared to participants' opinions. The controls that were changed by the participants were placed on the image in the positions they were placed at and controls that were not used were greyed out. The comments refer to remarks the participant made regarding the control the comment is placed next to.

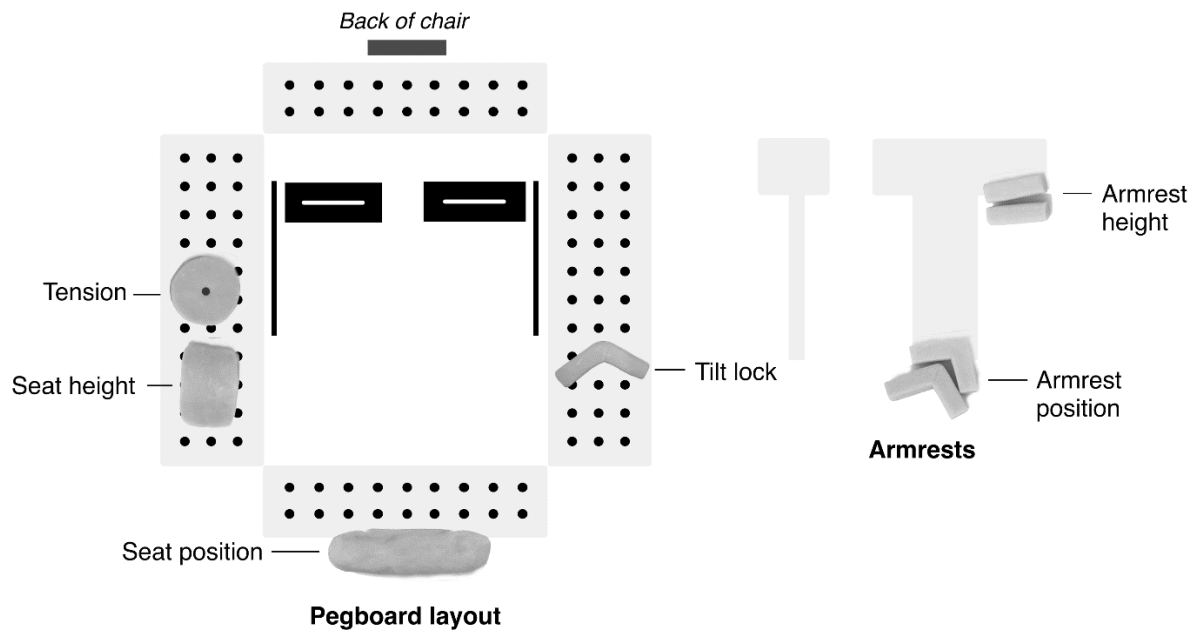


Figure 8, Original layout of the controls on the pegboard for the user test.

3.7.2. Analysis & Evaluation

The prototype tests were recorded with both audio and video to analyse the users' behaviour and intuitive reactions. The results were transcribed and again analysed in a KJ analysis grouped for each of the controls with focus on the understanding and pain points of use. The level of understanding was evaluated quantitatively and the preferred placement of controls across all participants was showcased with a heatmap. There were eight participants, all familiar with daily desk work and from a mix of design and non-design backgrounds.

3.8. Mental Model Evaluation

The strength of association for each control was evaluated in a matrix based on four factors, described in the table below.

Table 4, Factors making up the strength of association for each control for users

Factor	Source	Explanation
<i>Existence</i>	Benchmarking	How frequently the control is found in chairs
<i>Awareness</i>	Literature Study	How aware users are of the control's existence
<i>Understanding</i>	User Test	How well understood the use of the controls is by users
<i>Association</i>	Semantic and Function Analysis	How strong the associated metaphor is

The result is not a direct usability evaluation but rather a marker of how common and easily understood a control is. It uses insights from the previous report sections, comparing the benchmarking on whether a control is commonly found in chairs nowadays and examining four

literature studies (Vink et al., 2007; Hedge, 2016; Helander et al., 2007; Osvalder et al., 2013) that tested users' awareness of individual controls. Further the understanding of how to use individual controls was evaluated based on the user test in chapter 4.7, and finally the strength of each control's associated metaphor was evaluated based on insights from the function analysis and usability literature. This gives insight into which controls have a 'standard' that should be adhered to in the redesign, and which are little-known and therefore necessitate a deeper look into how to make the control more available and understood to users.

3.9. Design Guidelines

Based on insights from all previous chapters, some principles for more intuitive and consistent use have emerged that are going to become guidelines for designing the controls going forward. The redesign follows general design principles (Norman, 1989; Norman, 2004; Jordan, 2002; Monö, 1997) and findings following out of the user study and prototyping in terms of both functional and aesthetic changes aimed to improve usability and appeal to modern contexts. The guidelines established are influenced by Norman's design principles (Norman, 1989), Jordan's guidelines for usability (Jordan, 2002) and the phases of use of office chair controls established by Helander et al. (1995).

3.10. Final Design and Second Prototyping

During the project it grew evident that the aesthetic of the chair should be updated along with a usability redesign. This is echoed by the participants in the interviews that expressed that it looked outdated and unmaturred. As the chair was released in 1986, compared to modern office chairs it should not be dismissed by today's consumers as an outdated product. The redesign should adhere to its original design philosophy and therefore also maintain the design characteristics of Ullmanstolen to take advantage of the positive brand recognition that Ullmanstolen offers in ergonomics. This redesign provides a basis for the form language of the new controls.

As the first iteration and test focused on the movement and layout of controls on the chair, the second iteration focused on shape refinement of the chair and control design. The results from the user test were used as reference to emphasise features and identify which movements could be communicated more clearly in the shape. Ideas were discussed and communicated through sketching and brainstorming sessions and in rounds of CAD modeling. The material and form mood board created as part of gathering requirements helped develop the aesthetics for the redesign further, along with the chair's form features guiding the updated chair and control design.

3.10.1. Evaluating the Control Layout

After evaluating the controls thoroughly, the conclusion was reached that the design of tilt lock and seat position control had to be reconsidered. Different concepts for the two controls were listed and evaluated in a decision matrix (Åsa Wikberg Nilsson et al., 2015). See Appendix IV A

and B for the decision matrices. The resulting final layout is described in detail in the results section (Chapter 4.9).

3.10.2. Prototyping of the Controls

After establishing the design of the controls on a detail level, they were prototyped in multiple rounds, each control requiring differing amounts of iterations. The prototypes of the new designs were created using FDM printing which could then be tested internally by the group, exploring different sizes, shapes and surface textures. The goal for the second prototyping iteration was to test the look and feel of the design features and see whether they translated into 3D. Besides evaluating the controls by themselves, a cohesive form language between the parts could be created. The attachment and manufacturing possibilities were considered in part.



Figure 9, Prototypes of various controls

3.10.3. Validation with a Full Prototype

Three of the usability requirements needed a physical representation of the design to be evaluated. These are accessibility of the controls from a seated position, discoverability without looking for the controls and providing reference points for use indication. Beyond that, the size and fit of the controls was evaluated, their stability and build quality to an extent and the suitability of their layout in use. A full physical prototype of the chair was built, by reupholstering and adapting an older model to test the look, shape and feel of the chair and the controls and to evaluate the usability requirements, mainly regarding accessibility from a sitting position, discoverability and to an extent giving use indication. The controls were placed on the chair without an attached mechanism so they could not be evaluated on feedback given on actuation. These results are presented in Chapter 4.10. The factors evaluated were:

- Size and fit in hands
- Suitability of the layout
- Reachability from a seated position
- Fulfilment of usability requirements
- Build quality

- Colour match of the colour/fabric choices

3.10.4. Colour and material choice

The choice for the material of the chair referenced the mood board (see Figure 31), requirement list (Table 6) as well as insights from the user interviews and the chair analysis to position it on the market. The materials chosen align with materials frequently observed in office chairs during the benchmarking. Initial colour selection was visualised in 3D, after which samples of upholstery fabrics and leather were collected in matching colours and seating-appropriate materials. The colour codes are based the Natural Colour System (NCS; Bergström, 2022) but the colours shown in this report represent a visual approximation as they had to be converted from physical samples into the digital and printing colour space.

The materials and their environmental impact were evaluated against each other. Evaluating with Granta was done in steps with applying filters with for environmental aspects, durability, flammability and production process. To then be able to pick a specific material, evaluation between charts were used to find the material with the highest or lowest score in the chosen categories. When a suitable material had been chosen, a validation was then done with the material's typical usage categories in Granta.

4. Results and Analysis

This section describes the outcomes of the individual project phases, divided into a discovery phase with an analysis of Ullmanstolen and other chairs, defining the problem through research, exploring redesigns in an ideation and prototyping cycle, and from user tests narrowing into the final result of the thesis.

4.1. Product Analysis

A background on the chair needs to be given to understand its use and the many settings the controls offer, as well as the chair's positioning on the market on original release. Beyond the experience and usability of the controls, which were tested through trying out the chair, working on it for multiple days and disassembling it, the Ullman chair was evaluated in terms of functionality and looks with a function and shape analysis.

4.1.1. A Pain-free Experience

The intended target audience are people with back or posture problems mainly but encompassing all people that have a sedentary job or spend long hours sitting, developing back pain in the long run. Bearing this in mind, the target user does not intend to buy a medical product when looking for an office chair, but rather a good-looking chair that is going to support them in leading a healthier, pain-free life better than similar chairs. The chair was designed to support easy switching of positions, between a relaxed state leaning against the backrest, tilting backwards to distribute weight and support the arms with an unlocked backrest to an engaged forward-sitting position akin to position taken during horse-riding facilitated by cut-off corners at the front of the seat (P. & J. Ullman, personal communication, January 2024). The seat's unique shape with a downwards slant also serves to relax the hamstrings and place the legs comfortably under the chair.



Figure 10, Promotional material illustrating Ullmanstolen's possible sitting positions

4.1.2. Aesthetics of Ullmanstolen

Ullmanstolen has distinct design characteristics with a clear recognisable repetition of shapes in the components of the chair. One of the main identifiers of Ullmanstolen are the clean and flat surfaces with curvature happening between the transition of these main flat surfaces. This means no use of bi/double curved surfaces, where a surface is bent two times. The surfaces consist of quadrilateral shapes such as the rectangle and trapezoids, which together with each other creates slanted octagons that make up the overall shape of the seat and backrest. An exception to the geometric pattern is the middle of the armrest, where the top is connected to its holder. That part has a large fillet connecting the two parts which is an anomaly in the

geometric build up. The purpose of it is to make the armrest feel stable and connected to the holder of the armrest as it would otherwise be isolated and disconnected to the rest of the chair. Other anomalies to the design characteristics are most of the controls for the chair which do not match with the identifiable structure that the other shapes the product consists of.



Figure 11, Analysis of the chair's shapes

A recurring finding from the user study, detailed later on in the thesis, was that the chair did not look comfortable due to its sharp edges in comparison to other office chairs. Norman mentions in his book *Emotional Design* that sharp objects have a negative visceral effect on the brain while rounded smooth objects give rise to positive effects (Norman, 2004, p.29-30). Therefore components with sharp features i.e. seat and backrest, could be smoothed to make it more appealing and inviting for people to want to sit on it. The control design should be functional and allow for the desired movement, while visually belonging to the chair. So, if a particular movement demands a specific shape to communicate its use, the control design is determined by this movement. The shape details not determined by function should be consistent across all controls and adhere to the chair's form language. Helander (2003) stated that users were better able to distinguish aesthetic factors than ergonomics, which indicates that aesthetic features will make clear which part of the chair to interact with, signaling a control. This is further exemplified by one of the interviewees expressing that the different designs for similar types of rotating controls of Ullmanstolen, regarding adjustment of the backrest tension, backrest position and armrest position, were confusing. Not using consistent design language makes people less likely to interact with some of these controls as they might consider them to be a structural component of the chair. The senses suitable to target for the usage feedback are haptic, visual and auditory because those are known and expected and can enhance the user experience.

4.1.3. Analysis of the Controls



Figure 12, Ullmanstolen, model Q-lite

The Ullman chair has six controls, to adapt or change the seat height, distance between the seat and backrest, resistance of the backrest, movement of the backrest, height of the armrest and width of the armrest. The headrest can also be adapted but is not going to be considered as one of the controls during the project.

Seat Height Control

The seat height control is placed on the right side of the chair on a lever that is twisted through a shape of the control that needs to be pulled up. The shape of the control has a convex top part with a flat bottom where grooves exist that indicate correct placement of the fingers.



Figure 13, Seat height control

Backrest/Seat Position Control

The control for adjusting the backrest position is located in the back right of the chair on a stick that is rotated using a large hexagonal knob.



Figure 14, Backrest position control

Tension Control

The tension control is located underneath the seat, directly next to the gas spring. Its control is a large round knob that can be turned to tighten or loosen the torsion spring, changing the resistance the backrest provides when leaning backwards. It runs counter to the 'righty-tighty, lefty-loosey' mnemonic from a sitting position as the control is oriented pointing towards the ground, so a turn right when seated results in a loosening of the seat.



Figure 15, Tension control

Tilt Lock Control

The tilt lock control shares the same shape as the seat height with an exception of not having a flat surface on the underside, instead being hollow. This control is placed in the opposite side of the seat height and is moved in to lock and out to unlock. The control can only be locked when the seat is in an upright position.



Figure 16, Tilt lock control

Armrest Height Control

The armrest height control is placed on the outside of the armrests halfway between the top of the armrests and the base. They are used to raise and lower the armrests incrementally by twisting a small protruding ledge, similarly to setting a kitchen timer.



Figure 17, Armrest height control

Armrest Position Control

The armrests are attached by screws to the bottom of the seat with slots. The screws have large grips that can be used to loosen them to allow pulling the armrests outwards or inwards before re-screwing them.



Figure 18, Armrest position control

Headrest

The headrest is an integral part of the Ullmanstolen design due to its unique look and its functionality is not going to be addressed in this report. The height at which it sits can be changed by moving the pillow up or down since it is counterbalanced by a weight at the back of the chair, attached with a leather strap.

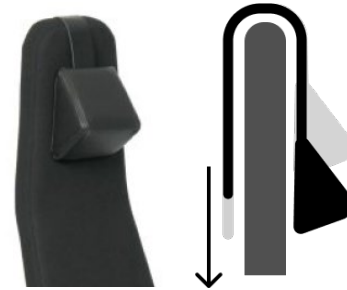


Figure 19, The headrest

4.1.4. Function Analysis

One setting can express and fulfil multiple functions, so for each of the settings, the different functions were listed as seen in Figure 19 below. The function of the seat height, as was explained in chapter 3.2 and illustrated in Figure 3, can for example be described as ‘to raise and lower the chair’ in the simplest terms. Beyond that, what should the seat height control express to a user in interaction? In the function analysis (Monö, 1997), different functions that the control should express during use were brainstormed and noted down, for each relevant control. Each descriptor communicates an intent of the goal. For the seat height, some are to *indicate direction, direct grip, conform to norms, provide feedback*. While these terms skew to the general, they often describe a deeper goal for interaction. The seat height control should for instance *provide feedback* on in/correct use of the control and indicate that a setting has been changed.

Seat Height	Seat Position	Tension	Tilt Lock
conform to norms	Convey back/forth tran...	give access	show un/locking
indicate direction	afford grip	provide feedback	give feedback
direct grip	provide feedback	indicate tightness	• haptic
convey heft	provide stability	be reachable	• auditory
draw the hands	indicate mechanism	be quick	be visible
provide feedback	express movement	indicate movement	provide solidity
	indicate placement	indicate change	
	actuate quickly	communicate intention	

Armrests	Armrest Height	Armrest Position	Headrest
support arms	adjust continually	effortless movement	offload weight
provide grip	provide feedback	communicate horizontal	provide support
shift positions	call to act	provide feedback	cushion head
bring flexibility	identify connection	identify position	change position
follow silhouette	indicate movement	allow symmetry	direct feedback
provide stability	alert senses	control movement	adapt to neck
express comfort	establish symmetry	provide contact	free movement
communicate unity	afford power	visually attract	indicate boundaries
	communicate family	communicate family	
		provide grip	
		be reachable	
		alert senses	

Figure 20, Function analysis of the different mechanisms

4.2. Benchmarking of Office Chair Controls and Associated Movements

For each of the chairs looked at in stores or at the furniture fair, the mechanisms and corresponding type of controls were documented and are going to be evaluated in this section. The type of mechanisms present in office chairs are listed in the *Mechanisms* table below. A more detailed breakdown is shown in appendix I.

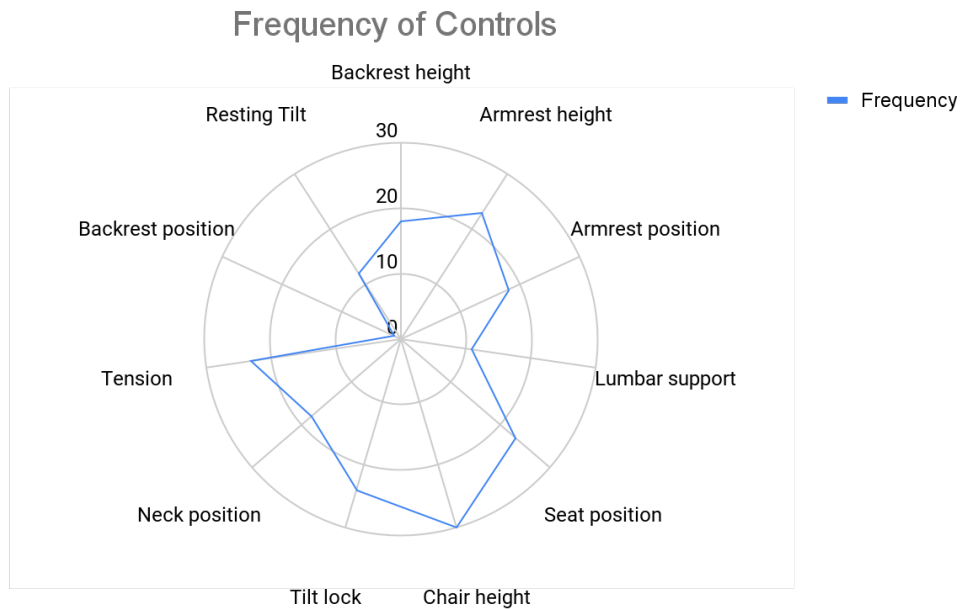


Figure 21, The frequency of each setting occurring across the analysed chairs

Overall, 30 chairs and their controls were evaluated while visiting the stores Ergona, Kinnarps, Nordiska Galleriet and the Stockholm Furniture fair. The categories of movement were split into rotational movement, a pulling motion or a pressing motion often combined with pulling. These were split into sub-movements based on the control design and hand movement needed to operate the control. Out of the 200 mechanisms listed as present, around 150 were considered in the evaluation of the control movement. Overall there were an average of five different control types present per chair. Changing the backrest position is an outlier because only the Ullman chair uses this function instead of moving the seat to change the amount of available seating space on a chair.

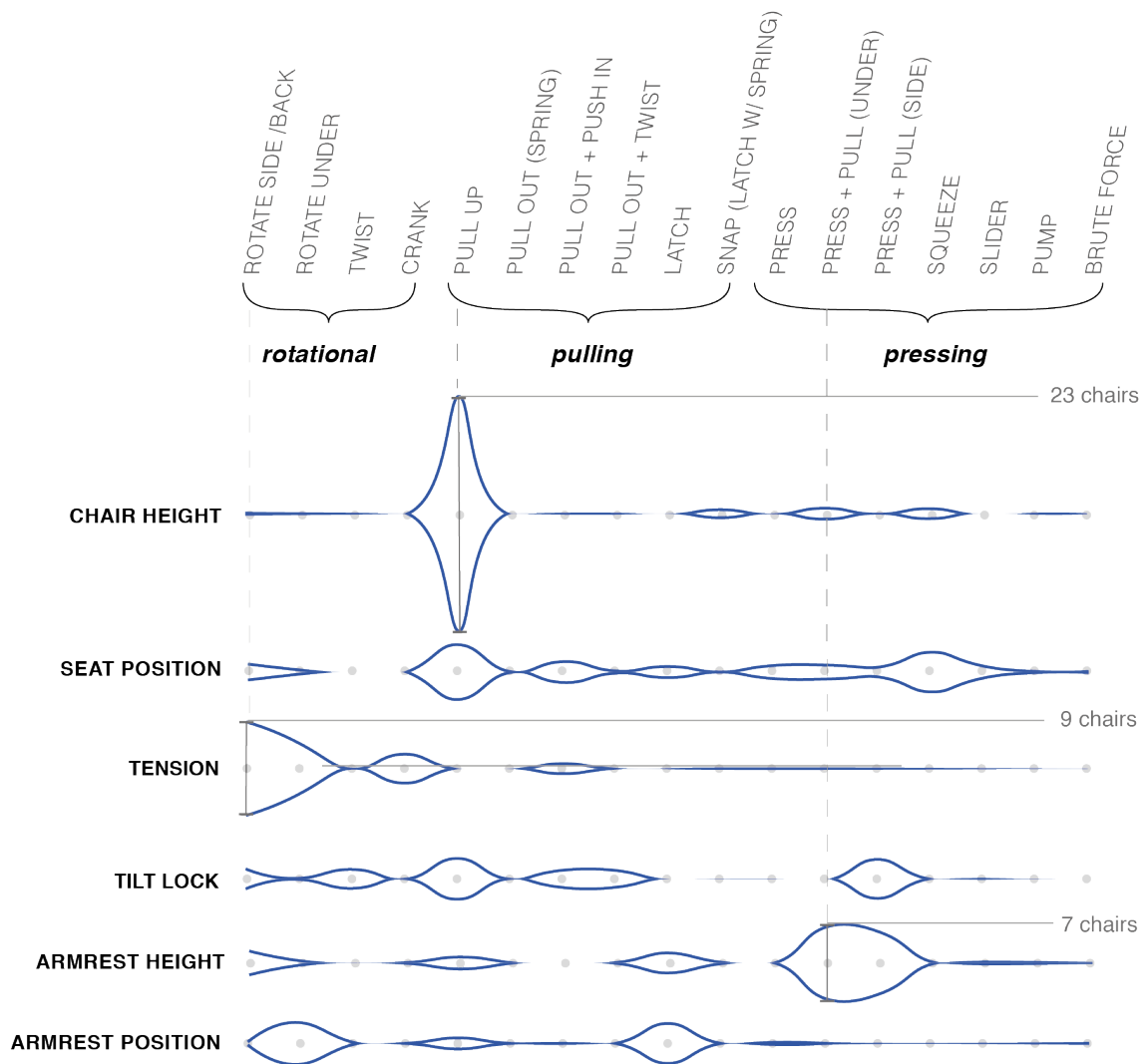


Figure 22, Benchmarked office chair controls grouped by movement type (full graph in appendix I. C)

Out of the ten mechanism types considered (backrest position being equivalent to seat position), the chair height was always present and also had the least deviation from the ‘pulling up’ motion, indicating that it is standardised and has a strong corresponding mental model in users’ minds. Both changing the seat position and the backrest height had the least consistency in type of control, with nine different control types identified for each. The ‘pull up’ control was the most frequently used motion, with the *pulling* motion in general also being the most frequent, before *pressing* and *rotational* movement seen least, though in a similar number. The *rotational* movement was most often placed on the side of the chair, or underneath, with some placed at the back. The ‘press and pull’ motions were also most frequently placed sideways, or underneath the chair component to be changed. This control was mostly used for changing the armrest height.

Table 5, The most common control associated with each mechanism

Mechanisms	Most Common Control Movement	Most Common Placement
Backrest height	Press + Pull	Side
Armrest height	Press + Pull	Side, underneath
Armrest position	Latch & Rotation	Underneath
Lumbar support	Pump	Back, side
Seat position	Pull up & Squeezing	Front, side
Chair height	Pull up	Side
Tilt lock	Pull up & Press + Pull	Side
Neck position	Pull up & Brute Force	At neck
Tension	Rotate	Side, back or underneath
Backrest position	Rotate	Back
Resting Tilt	Pull up & Latch with spring	Side, back

Most of the chairs evaluated had at least six out of the ten mechanisms for adjustment present, with around a fourth of chairs having all of them (disregarding the backrest) and some even having other adjustments present that were not listed, such as switching between synchronous and asynchronous seat/backrest movement, changing the height of the footrest or angle of the armrest. One particular brand seen at the furniture fair, Humanscale, relied on self-adjusting mechanisms instead of controls, arguably making their chairs more intuitive as the user does not need to change any settings themselves. 24-hour seating as offered by Kab Seating and Svenstol distinguishes itself through branding and the shape and material of the chairs, which are often wider, stiffer, heavier and designed to resemble a sofa more than a chair and not very relevant for our needs.

The Ullman chair has six out of ten of the mechanisms, excluding the lumbar support, backrest height (which indirectly adjusts the lumbar support), neck position and resting tilt. The choice to exclude lumbar adjustment was made deliberately by the company (P. Ullman, personal communication, n.d.) and it has also only become a trend in recent years. The neck rest and resting tilt especially could be considered to be added in a redesign, but the main issue of the chair is not that it lacks controls but that the controls are significantly harder to understand and use than modern chairs.

4.3. Analysing the User Study

The following section describes the outcomes of the survey and the interviews conducted. The results of the survey are twofold, once from the Ullman chair users and Kinnarps chair users, for it to be able to be compared in terms of the usability and comfort of the chairs. There were a total of 15 people testing the chair, with 11 people trying the Ullman chair and 4 people trying the Kinnarps chair, so while a statistical conclusion cannot be drawn, a general trend can be analysed.

4.3.1. Results of the User Survey

The first topic of the survey concerns the usability of the controls. All users, with the exception of two testing the Ullman chair, changed at least one control (see Figure 23). In the Kinnarps chair test that consisted of four people, most managed to use the controls as much or more than the nine Ullman chair testers, as seen in Figure 24.

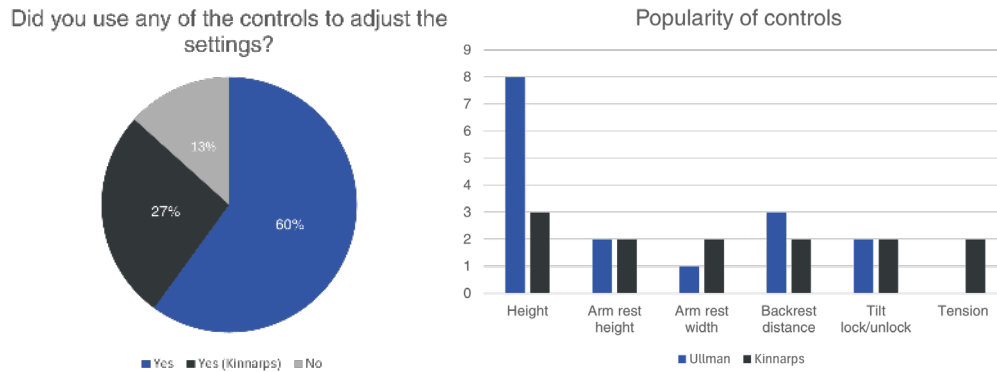


Figure 23 & Figure 24, Pie chart of how many users changed a chair setting & bar graph of the most used controls.

The only control most people changed and was able to find on all of the chairs was the seat height. The results from Figure 24 shows that the discoverability of the desired controls in the Ullman chair is poor in comparison and that users are not able to make use of the full ergonomic potential of the chair with the current controls layout and use. Which means that the usability of most of the controls are insufficient and that the semantic expression does not match with the user's mental model.

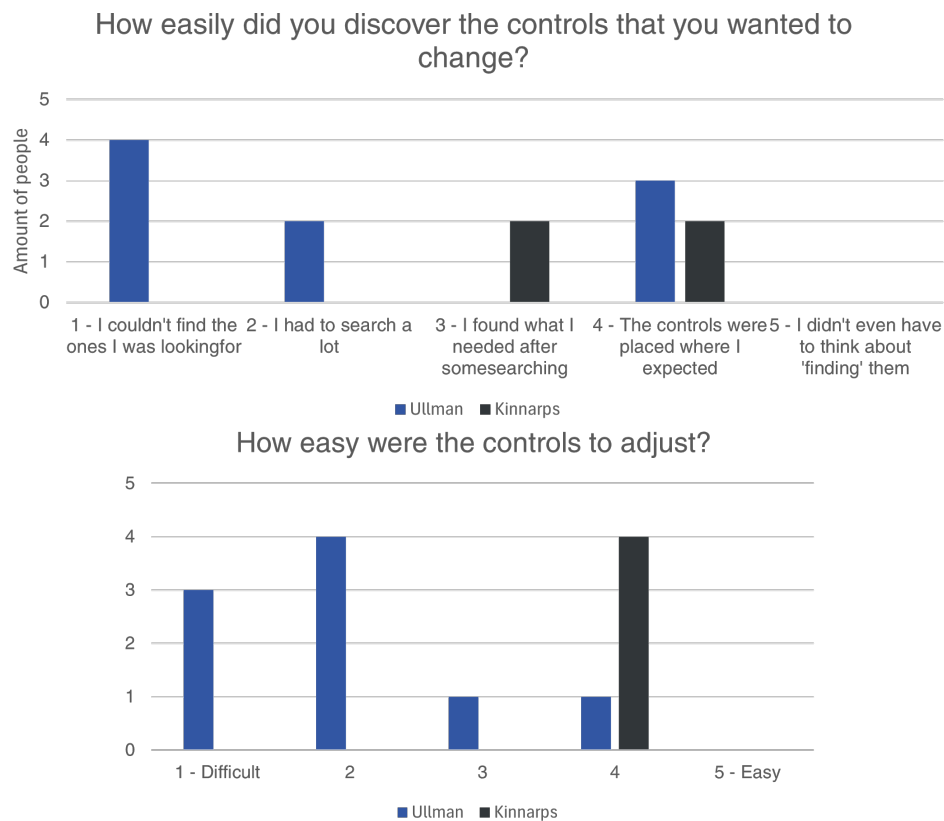


Figure 25 & Figure 26, Bar graphs showing the users' perceived discoverability and adjustability of the controls.

There were three people who stated that it was easy for them to discover their desired controls, but they only changed the seat height, except for one that also changed the tilt lock. This further indicates that the seat height placement and movement correlates to an established mental model. While the tilt lock placement is good, as many people interacted with it, most were not able to understand what function it had or how to use it. These conclusions are supported by the quote from the person below only being able to change the seat height.

“I felt like I found it by luck, the first lever I tested worked (seat height). But I think I couldn't guess what it does based on visuals. The left lever, for example (tilt lock), I do not understand what it does. I also changed one thing only (seat height), which is not that complicated”

Question about what they liked or did not like about the controls

This quote exemplifies the need for visual clues in understanding what the different controls do. The two people that only changed the seat height also gave the Ullman chair the most favourable score in how easy it was to adjust the control with the only scores of three and four respectively out of five. This means that apart from making it easier to find the controls and understand what they do through haptics and feedback, emphasis needs to be put on the effort it takes to adjust them. This helps to minimise the physical effort but also the mental load of figuring out what a control does. Even if a person knows what a control does doesn't mean that the person knows how that control is supposed to be used to be ergonomically correct. The addition of haptics and feedback could help to create reference points to minimise the decision making and fine tuning of the controls to their liking. The bad ergonomics and lack of understanding for the use of the controls are exemplified by the two quotes below.

“The controls for the armrests were tricky - rotation of the the control next to the rest itself (twist hands in an unnatural position)”

“Hard to notice, a friend told me how to change it for me!” (regarding the tension)

Question about what they liked or did not like about the controls

The Kinnarps chairs were rated three to four out of five points in finding the correct control as well as a four in how easy they were to adjust. This may be due to the consistency and proximity in placement of the controls, mainly on the sides of the seat and on long levers. Placement on levers is preferable according to *Ergonomics of Ergonomic Chairs: a Study of Adjustability Features* by Helander et al. (1995). This usage of controls is in part a learned behaviour, as most office chairs uses a lever for the seat height control, which is the epitome of an office chair. Placing controls closely to one another also facilitates finding new controls while interacting with another control.

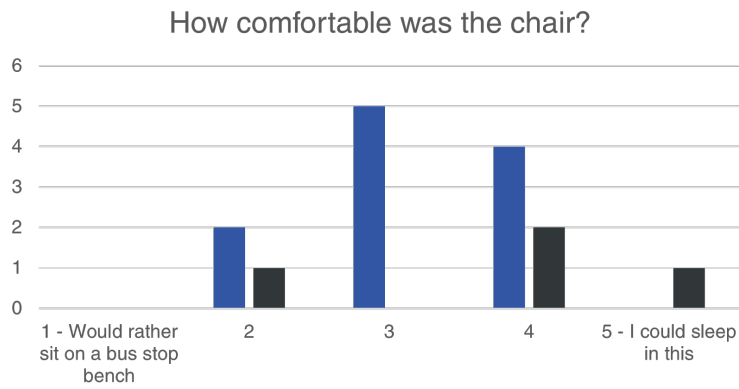


Figure 27, Participants rating of perceived comfort

Regarding comfort, the deviation was less drastic with mixed results between the chair brands (see Figure 28). The sitting positions that they filled out according followed a curve, with people mostly sitting in the upright A and B position during their work (see Figures 29 & 30 below). This shows that the full potential of varying their positions was not fulfilled for most. The results also show that in terms of percentage, Kinnarps chairs' testers sat in more varied positions.

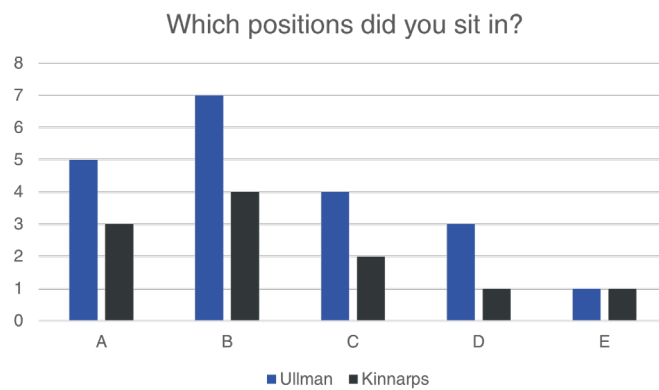


Figure 28 & Figure 29, Informative picture on the user survey, Ullmanstolen promotional material & the number of positions sat in

4.3.2. Perception of the Ullman Chair

The answers from the interviews in combination of the open questions in the survey results were analysed using a KJ analysis resulting in groupings of topics within each separate component or control of the chair.

General Perception

The general understanding of the controls for the chair was poor with most people giving up trying to adjust them. The people who did try to adjust the controls expressed the need for visual indication of what the controls do as a cue to using them. Multiple controls having the same shape, for example the seat height and tilt lock, created confusion for users. Further, dissatisfaction was expressed by the lack of cohesion in some of the control's designs. It was not obvious to users whether some of the controls were a part of the construction of the chair or a setting to change (i.e. the armrest width control being a screw with a larger handle for screwing out the armrests). It was expressed by the users that they did not like the looks of the chair referencing its simple geometric shapes to the chair feeling very basic and unmaturred in its design. The geometric shapes also convey an old-fashioned look, and with the combination of sharp corners and slim backrest the chair was said to look uncomfortable to sit in. A conclusion can therefore be drawn that the chair's looks should be updated so that all parts are coherent with each other as well as improving appeal to the current market.

Seat

The usability of the seat height control was considered sufficient by most people, except from some that expressed a confusion between discerning the tilt lock and seat height adjustment. Another complaint was on the gap that the control had before activating creating a dead space that makes the control feel hollow and unresponsive making a rattle that lowers the qualitative feel. The overall comfort of the chair was considered to be good, but everyone would have liked it to be softer than it currently is. An interviewee with expertise in upholstery said that the stiff foam is beneficial to support the ergonomic position but would feel uncomfortable after a long session of sitting. That person also suggested that a softer foam could be placed on top of the stiff foam as to compensate for each other's features.

Backrest

The concept of moving the backrest was unusual for the participants and as a consequence most people did not adjust it. One person used to adjusting the seat said that they expected to find it in the front just as in a car seat, but they gave up searching as they were unable to find it. After the setting had been explained, the same person thought that it makes sense to move the backrest as it is the same principle ergonomically as moving the seat. Placing a control at the back is therefore not ideal as they will not see it and therefore think that it does not exist. Regarding the ergonomics of the chair it was expressed that the back was too narrow, creating a feeling of lack of support and that there was a wish for more lumbar support.

Tension

The tension control was a control that no one changed during their testing and when asked to change it most did not understand what it did and were unable to identify its location. When asking them to try the control after having shown them it they were not impressed as these two quotes below explains when trying to adjust it.

“I can't feel the difference. Yeah, and I turned it quite much now. Yeah, maybe a little bit easier, but I have twisted it quite a lot trying to understand what it's doing.”

“I thought if I continue twisting it, it will break something or that I will disconnect the seat from the chair.”

Quotes from interviews relating to the tension control

For a person to be able to use this control they need to have previous knowledge about office chairs to know where to look for the control as well as having patience and understanding of the mechanism to be able to adjust it accordingly. The participants also expressed a frustration in the placement as adjusting it either means turning the chair upside down or hunching over the seat in an uncomfortable position. This with the addition of hidden placement and the number of rotations needed to feel a difference resulted in the control never being adjusted.

Tilt lock

Many of the interviewees found the tilt lock control and tried to use it, however they often had no idea what they changed or on receiving no feedback on what changed after using the control, left it and moved on. The interviewee who was familiar with the tilt lock function was surprised it was unable to lock in any position other than straight up. Since the shape of the tilt lock control resembled the seat height on the opposite side, some interviewees expected being able to also push the control up and down and did not try to push it in. Three people remarked that the shapes of the two mechanisms were too similar, causing confusion. Regarding the locking function in general, there were different preferences on locking their own chair, with some changing the position throughout the day, some unlocking for casual interactions and some leaving their chair locked all day.

Armrest Height

Most expected to be able to simply pull up the armrests to change the height, possibly by first unlocking a control. Interviewees expressed that the twisting motion for raising the armrests was hard to do and still, as the control offered a lot of resistance. Opinions on whether the incremental change of the height was beneficial for adjusting both armrests to the same level or not were divided

Armrest Position

One person mentioned that it feels like a structural component of the chair, so they expressed worry at unscrewing the chair and later did unscrew both armrests, not managing to reattach them easily. That there was also no symmetry in adjusting these armrests was mentioned. One

interviewee did not find the adjustment and remarked that they would prefer the armrests set wider apart.

Headrest

The headrest was perceived as simple and visually not part of the chair. The corner supporting the neck felt sharp and pointing into the neck to multiple interviewees. One user remarked on missing a horizontal adjustment for moving the headrest out from the back of the chair. This lack of adjustment created an impression of a budget chair, as one user commented. The weight that balanced the height of the headrest was loose and users disliked that it made a slapping sound against the back of the chair when they were tilting in the chair.

Insights from the long-term user

The interview with the long-term user resembled responses from the first-time users. Visually clarifying the setting in the control was lacking for ease of adjustment. The user preferred learning the controls by trying rather than looking at a handbook. Consequently, they only changed the seat height in day-to-day use and were unable to recollect other controls functionality, most often being unaware of a control's existence at all. The controls and their functionality were explained to the long-term user in a later part of the interview as a response. The tension control, located at the bottom of the seat, presented a problem due to its position and difficulty in adjusting and adjustment of it was quickly abandoned by the user during the interview. This similarity to the interviews with short-term users presents an interesting finding as it indicates that longer time spent with the chair does not increase knowledge about its settings and controls. It should be noted that the long-term user is a practicing industrial designer and displayed curiosity in understanding the controls throughout the interview, turning the chair upside down to access controls and getting other chair models for comparison to be able to provide more detailed feedback. While variations in the understanding of office chair mechanisms correlate with curiosity to learn them to some extent, a lack of interest in learning was not the case here.

The long use duration does indicate that the chair is well-made and durable as well as comfortable enough. The user had recently bought a second, more recent version of the Ullman chair, reason being that the quality was very good. Further, the 20-year-old Ullman chair was still in use. Though not the focus of this work, the quality of the newer version was perceived as lesser because it uses too much plastic, creating rattling noises, especially in the armrest while adjusting.

4.4. List of Requirements

Following out of the literature, market and brand research, a list of requirements was created that is used as a guideline for the ideation, redesign and testing of the controls.

The requirements are grouped into the following sections:

- I. *General* - Aspects of the current Ullman chair that should be kept or improved without directly relating to the goal of this work
- II. *Usability* - Requirements that embody a 'easy-to-use' control, based in the design principles researched previously
- III. *Aesthetics* - Semantic features that communicate a well-design and appealing chair and support the usability aspects
- IV. *Accessibility* - Guidelines on who the chair should remain accessible to, to consider during the design phase

Table 6 pt. 1, The list of requirements resulting from the research (0 - wish, 1 - least to 3 - most important requirement)

<i>Requirement</i>	<i>Description</i>	<i>Quantification method</i>	<i>Importance</i>
General			
Maintain ergonomic aspects	As extensive ergonomic research is the foundation of the chair's design, changes to these aspects should be minimal and founded.	Conversations with the creators will be held to adhere to their standards.	3
Maintain simplicity	Maintain simplicity, low cost and longevity by not introducing electronic components and maintaining repairability.	No electronic components are introduced.	0
Usability			
Follow a mental model	Adhere to common associations users have and employ metaphors as guides when possible.	Describe the mapping & design changes based on known principles.	2
Controls are accessible from a sitting position	Users should not need to stand up or change position significantly to find and use the controls.	Usability tests regarding shape and placement.	3
Be discoverable without looking	The user should be able to find all controls by hand only, as users typically do not look at the chair.	Usability tests regarding shape and placement.	3
Provide feedback	Provide affirmative feedback on actuation (visual, haptic, auditory).	Usability tests & motivating design decisions.	3
Give use indication	Provide reference points indicating correct use and current setting of the control.	Usability tests & motivating design decisions.	3

Table 7 continued, The list of requirements resulting from the research (0 - wish, 1 - least to 3 - most important requirement)

<i>Requirement</i>	<i>Description</i>	<i>Quantification method</i>	<i>Importance</i>
Aesthetics			
Adhere to the chair's philosophy	The Ullman design philosophy is grounded in creating smart solutions for the problem. The solutions are therefore not overly complicated and use simplicity to their advantage.	Adhere to the semantic analysis of the chair.	1
Suggest comfort	Be perceived as comfortable by users.	User evaluation & motivating design decisions.	3
Appeal to the current target group	Align with current user's expectations of an office chair and evoke a positive response.	User evaluation of the redesigned chair	2
Consistent design	Repeat an established form language across the chair body and controls, to be perceived as part of a whole.	Semantic evaluation & motivating design decisions.	1
Accessibility			
Be usable with one hand	Provide a higher level of accessibility and easier use.	Usability tests.	0
Sustainability			
Design for disassembly	The components should be able to be dis/re-assembled with home tools, by a customer without deep knowledge.	Use of non-destructive, commonplace fasteners.	2
Maintaining longevity	Use high quality materials that last long and age well.	Choosing suitable materials with a high Martindale index.	2
Supporting repairability through replacements	The company can provide replacement parts as the chair is designed for disassembly/reassembly and therefore the chair could be used for longer.	Provide instructions as well as replacement parts to the user.	0

4.4.1. Style Guide

As an addition to the requirements list, a mood board acts as a style guide. The images represent the working environment, materials and styling to serve as inspiration.

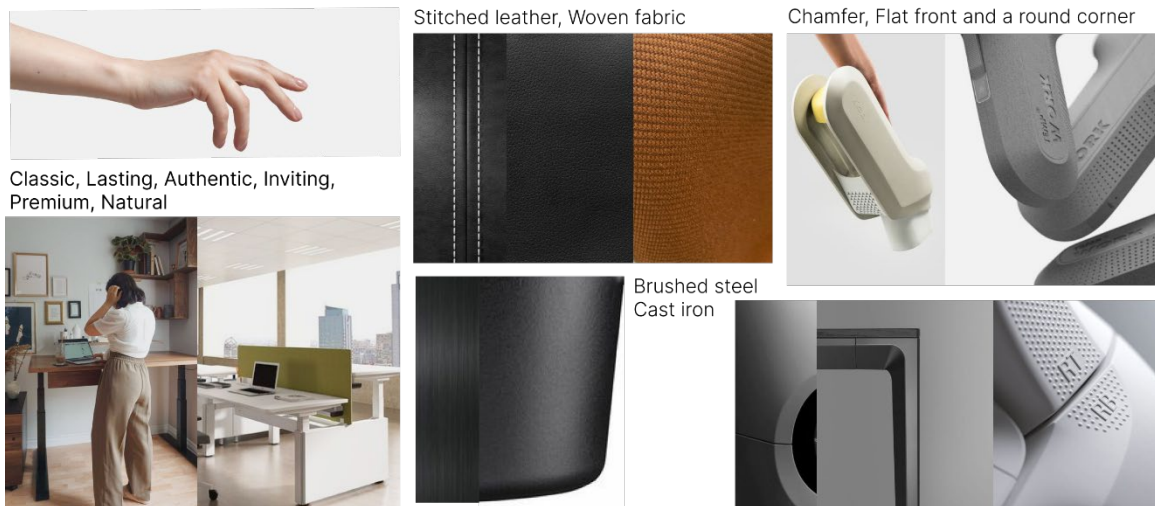


Figure 30, Inspirational mood board for the chair and control redesign

4.5. First Ideation and Prototype Design

This section describes the ideation and prototyping of the first draft of chair controls. These focus on the use and layout of the controls on the chair, to provide a basis for analysing in what way the different settings are used and where users would typically place them.

4.5.1. Clay ideation

Below, the shapes for each of the controls, made from clay are pictured and explained. The armrest height and position are grouped as these controls were designed to match each other in shape, indicating belonging to the same part of the chair. The models are intended to illustrate different possibilities for movement for each control, such as rotation, pulling, flipping a switch, etc. This should give users freedom to choose their preferred way of use in a later user test.

Seat height control

The seat height control was shown to have a strong convention for the movement and placement associated with it, mostly using an upwards pulling motion, and placement under the right side of the seat towards the front. Therefore mainly alternative shapes supporting better grip were explored rather than separate movement types. Some shapes also explore the possibility of pushing the control down for the seat to lower itself instead of pulling it up while seated. This creates a clearer association of the lever direction corresponding to the seat movement.

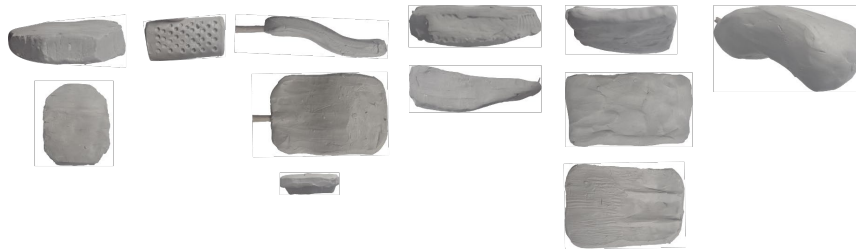


Figure 31, Clay ideation of seat height control shapes

Seat position control

Changing the seat position is accomplished in a number of ways on the benchmarked chairs, with the only convention being that the control is placed on the seat - either at the front or side. Here, Ullmanstolen differs by activating the backrest movement, with the control placed at the back of the chair. The shapes explored for this control intend a motion of squeezing or pulling upwards into the seat, moving the seat backwards and forwards after actuation.

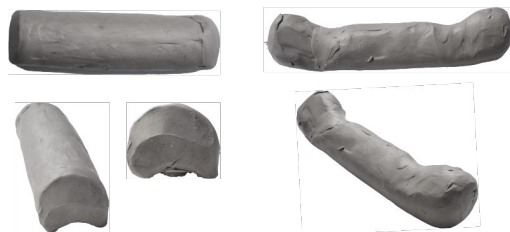


Figure 32, Clay ideation of seat position control shapes

Tension control

The tensioning, or tightening, movement is most associated with the turning of a screw or winding up a spring, which are rotational movements. Therefore a solid cylindrical or round body was chosen to indicate rotation with the hand. Different profiles were explored to improve grip and indicate the set position.



Figure 33, Clay ideation of tension control shapes

Tilt lock control

The locking of the backrest is a setting quite unfamiliar to many users and its corresponding control had the least movement convention in the benchmarking, with some using rotation, pushing, pulling or a combined pull-and-twist movement. To refer to a binary movement - locking/unlocking – the control designs explored are only usable in two states, opening and closing or sliding between two placements.

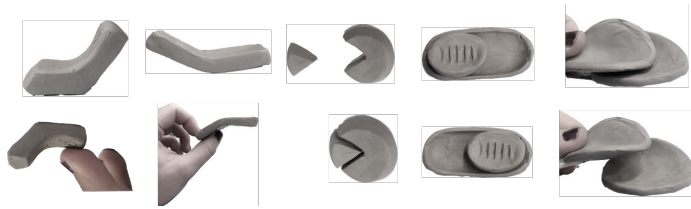


Figure 34, Clay ideation of tilt lock control shapes

Armrest height and position controls

The armrest controls mainly use a press-and-pull action or a latch to activate them. Since they are typically placed on the armrest itself, focus was put on creating controls that indicate finger placement which facilitate a dragging motion. A tie-in to the tilt lock shape was also explored to match shapes.

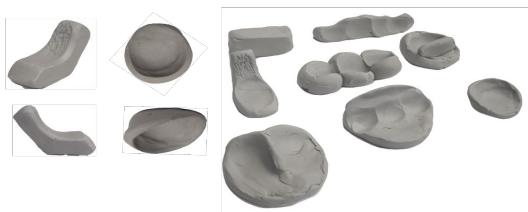


Figure 35, Clay ideation of armrest control shapes

4.5.2. The Prototype

After the ideation with both sketching and clay, final versions of the controls were modelled and baked to use for prototype testing (see Figure 31). Their shape is meant to give indications on their use, such as a round control facilitating turning and a long flat one a full-handed grip but no explanation was given to evaluate how users respond to the different shapes.

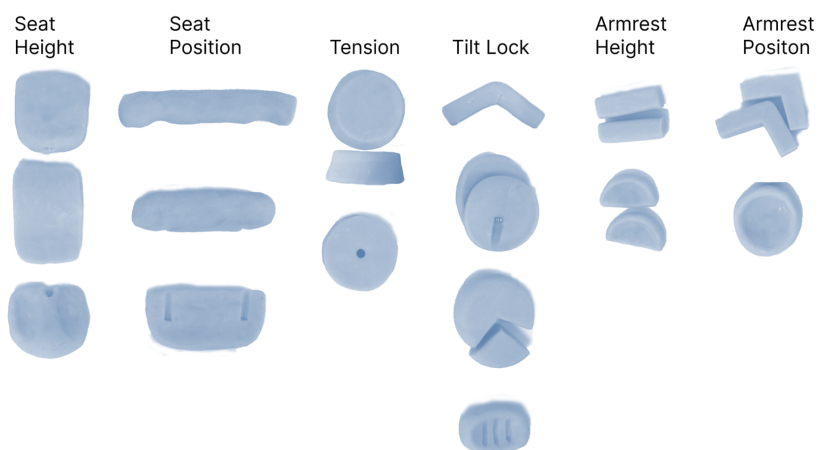


Figure 36, Clay prototypes of the controls

The layout of the controls as placed on the pegboard for user testing is illustrated below, in Figure 32. The tension, rotational, is placed on the right side of the seat, behind the seat height lever. The tilt lock is placed opposite on the left, with a switch type mechanism and the seat/backrest position is a squeeze lever below the front of the seat. The armrest controls are placed on the armrests, height below the front top armrest, the width/position at the bend of the armrest under the seat. It is important to note that participants were not told which shape

was associated with which control to allow an exploration of the different movement types and find out what they preferred (see Figure 8 in the methodology section).

4.6. User Test

This section outlines the results from the prototype test, discussing user understanding in terms of control shape and placement on the chair. Details on how the test was set up and conducted are found in the Methodology section, chapter 3.6 from page 13.

4.6.1. User Understanding of the Controls

Apart from a strong use and placement convention shown in the seat height control and a clear association between a rounded shape for the tension being associated with a rotational movement, there were varied results in understanding and choice of controls. Users had most difficulty with the tilt lock and armrest position control, explained in more detail below.

Seat height

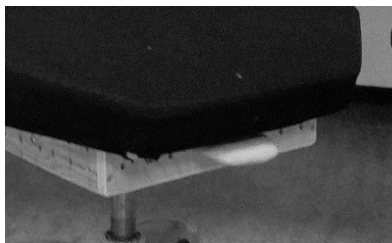


The control is flat and elongated with a wave shape to indicate finger placement and was placed on a lever to lift up (see Figure 33). This control was understood best, with all participants finding the control and only one choosing the designated 'seat position' shape instead, referencing the seat height in that participant's office chair.



Figure 37, Placement of the seat height control during the user test

Seat position

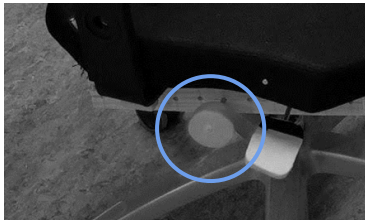


The seat position was not clear to most participants and depended on whether they had either encountered it before or related it to the control's placement in cars. An observation regarding how the participants were sitting and their success in finding the seat position control was made, where most women sat with their legs close or crossed which obstructed the control and made it less likely to look for a control in its location. None of the participants that chose incorrectly picked the same control for an alternative interpretation of how the seat would move back and forth. The only control that was not picked was the armrest height control.



Figure 38, Placement of the seat position control during the user test

Tension



The tension control was placed on the right behind the seat height, usable by rotating back and forth. It was understood well, with only one person choosing completely differently. Three of the participants choosing similarly were not familiar with a tension control and related the function to changing the angle of the backrest rather than its resistance. This highlights the importance of knowledge about the control's function.

Figure 39, Placement of the tension control during the user test

Tilt lock



intended placement



it balanced during study



The tilt lock control showed the least understanding among all controls, with six out of eight users choosing differently. The chosen shape, placement and the participants' understanding varied vastly, with four users sliding a control in/out of the seat, and three proposing two functions for the control. After an explanation was given, all participants understood its function but the placement and lack of haptic feedback of the control during the test hampered evaluation. The shape was not fixed in place as intended, therefore lacking indication for activation of the mechanism. The conclusion drawn was that the tilt lock setting and shape are novel for users and the control needs feedback for un/locking to be understood.

Figure 40, Placement of the tilt lock control during the user test

Armrest height



The armrest height was understood well by half of users, with half choosing differently - reaching for either the side or bottom of the armrest or not using the control at all and preferring to pull up the whole armrest. A commonality for all users but one was that they first reached for the top of the armrest. Most people chose to grab the top of the armrest when adjusting the height. Apart from the pre-placed button, a wish was to have a button on the side, right underneath the top of the armrest. One participant expressed that the arms feel constrained when using the control, having to excessively bend the hand forward at the wrist to be able to access the button. This explains why some of the people chose to access

the provided control from the side. It indicates that the placement combined with the armrests' rounded-downwards shape create poor ergonomics.

Figure 41, Placement of the armrest height control during the user test

Armrest position



Placed under the armrest underneath the seat, the armrest position control was intended to be pulled in/out or back/forth on the axes the armrests are intended to move along. The control was unclear, with less than half of users understanding its function. Even when the control was chosen, its use was perceived as confusing. This confusion likely stems from the shape, shown in figure 38. It affords gripping of two



perpendicular sides for actuating the control. The mounting of these V-shaped controls also allowed a spinning rotation, providing too many degrees of freedom and as a consequence the shape did not convey the intended interaction clearly.

Figure 42, The controls for changing the armrest position

4.6.2. Chosen Control Placements

The graph below illustrates the understanding users displayed of the pre-chosen controls and layout. A quantitative measurement was made for each control that indicates how well the users either understood the control or not (Figure 45). This scale is divided into four parts: did not use any control, speculated differently (choosing another control for the asked function), speculated similarly and understood immediately. After an explanation on the intended control shape for each setting was given, the participants were asked to personalise the setup and choose a placement of all the controls most comfortable to them. The heat map below shows an overlay of where the controls were placed by the participants. Most were very comfortable with the placement of the seat height and tension at the right side towards the front, the most established location for controls on any chair.

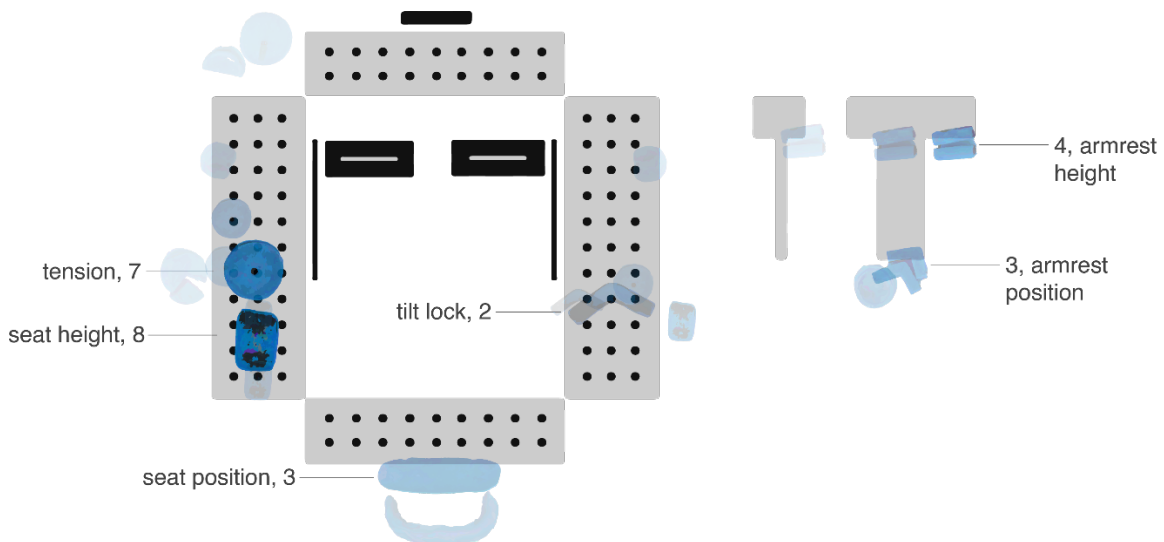


Figure 43, Heat map of the used controls during the testing, with higher opacity indicating more frequent use. The labels indicate the number of users choosing the pre-set control. The seat height was the most used mechanism.

The seat position was placed at the front by about half of the participants, and had the largest variety of differing mechanisms proposed, with seven different control shapes suggested - from large handles, a flat lever, a turning knob, to shapes rotating sideways or beneath the chair. It showed that there is no clear association with how the seat should be moved (by rotating, turning, pulling, pressing, pushing to unlock, etc.) so this control is very dependent on clear feedback to be understood. The tilt lock had a large variety of choices, some participants combining it with the tension control, and one user suggesting placing it as a lever behind the tension control. The chosen movements were for example to push the control up/down or in/out to un/lock the control. While placement for the armrest height and position varied, they were all placed on the armrest body itself with minor variations or left out completely to instead pull and push the armrests into the desired position directly.

4.6.3. Conclusions of the User Test

There were large differences in how well-understood the controls were. The seat position was clearly found and understood by most. With all controls there was some level of speculation and choice of different shapes or moving the controls in a way other than intended. Participants used past knowledge of controls as a reference, with that experience varying widely. Examples are users finding the seat position control based on having the same type of control in a car or forklift, or one user choosing it as the seat height control because that is how it is used on their office chair. Flat shapes for pushing, round shapes for rotating and handle-like shapes for grabbing had clear associations. The tilt lock, seat position and armrest position were the least understood controls, reasons being partly placement and fidelity of the prototypes but also previous knowledge on the existence and expected placement of the controls. Due to low fidelity and novelty of the tilt lock shape for instance, its shape failed to communicate what was expected of the user. For the seat and armrest position placement in a less typical location could be part of the low discoverability.

4.7. Evaluation of the Controls and their Associated Mental Models

This next chapter combines the insights gathered from the prototype test with findings from the research phase. After a broad investigation on the usability and understanding of controls, the findings are now evaluated in a matrix comparing the proposed controls with each other. The strength of the user's mental model regarding the individual controls plays a role in the design freedom and decision making. For a well-established and understood control, it would be counter-intuitive to change the common mechanism, shape and placement, whereas with a control that is little-understood and perceived as confusing, there is more freedom and incentive to change the design. Still, care needs to be taken to direct the use and give appropriate feedback. In a Pugh matrix in table 7 below, the strength of each control in terms of the user's understanding is evaluated using results from the benchmarking, literature review, user test and gestalt theory regarding shape metaphors. The control shape and placement referred to in the *Understanding* and *Association* sections refer to the ones in the original placement of the user test that have been illustrated in the previous chapter.

Table 8, Pugh matrix of the mental model strength associated with each mechanism

		Weight	Seat Height	Seat Position	Tension	Tilt Lock	Armrest Height	Armrest Position
Existence	Benchmarking	0,15	100,0	76,7	76,7	80,0	76,7	60,0
Awareness	Literature	0,3	60,7	17,4	14,9	30,2	46,6	50*
Under-standing	User Test	0,4	90,6	43,8	65,6	31,3	56,3	34,4
Association	Metaphor	0,15	50	80	60	70	80	70
<i>Strength of the user's mental model</i>			77,0	46,2	51,2	44,1	60,0	48,3
<i>Ranking</i>			1	5	3	6	2	4

*The average score for armrest position in literature

The control that ranks highest, as expected, is the seat height since it is present on all the chairs evaluated during the benchmarking and the only control with an established (discoverable) placement, with 90% of users in the conducted user test able to identify and use the control. It is weakest in the metaphor, where the pulling-up association is adequate for raising up the chair but having to pull up to lower the chair is incongruent with the same mental model, as exemplified by two study participants explaining they would push down on the control to lower the seat. Pulling up while using body weight to lower the seat relates to the gas spring's mechanism and is a learned behaviour.

The armrest height is frequently present and understood by most, with pulling up/pushing down the armrest to raise and lower being a very natural movement, following a consistent motion along the same axis as the part of the chair being adjusted. The armrest position was not specifically evaluated in the studies from the literature, so an average value was taken for it, close to the armrest height value as these were not differentiated in the research. It scored very low in the user test due to the prototype fidelity and as the only control allowing adjustment

along two axes. However, it follows the same motion as the armrest height, with a simple pulling/pushing in the intended movement direction of the armrest and should therefore be easily understandable by users, scoring high on the metaphor.

While the tension is also commonly present, only 15% of the participants of the studies evaluated in the literature review were aware of its existence, compared to 61% who were aware of the seat height control. This is likely due to the tension having the worst placement convention – right at the torsion spring underneath the seat – so it is not reachable from a sitting position and seen from neither a sitting nor a standing position. Further, even though the mental model of rotating to loosen or tighten is clear, the control is typically very hard to use as it has a lot of resistance and being placed to point down from the seat, the loosening/tightening movement is reversed from the sitting user's perspective.

The seat position had an awareness of only 17%, the second lowest and was understood by below half of the participants of the user test. The movement metaphor of dragging a seat forward and backward is quite direct, but what it intends to affect and where it is placed can be cause for confusion. Lastly, the tilt lock has the lowest strength rating. While the control is present in most chairs, awareness of it is low, with no placement or motion convention existing and understanding during the user test was only 31%, possibly due to prototype fidelity, which did not provide actuation feedback. This control provides a large space for learning and needs clear feedback on what use of the control affects.

4.8. Guidelines for Intuitive Design

In this chapter a set of guidelines for a redesign of Ullmanstolen is established, based on insights and concepts developed in the previous chapters. These principles aim to adhere to the user's mental models and create a more intuitive user experience. The concepts overlap to some extent and combine to create a better user experience. The guidelines are phrased in a general manner to be suitable for the design of other office chair controls or other controls used in a similar context. They are applied to the updated Ullmanstolen as described in a later chapter, chapter 4.9.

4.8.1. Design Guidelines

Mental Model

The controls should follow a clear mental model, ideally using the closest one available and most commonly understood and communicate that association clearly to the user.

- Simply dragging the desired part into the desired position (e.g. pulling up the armrest).
- Adhering to a common mnemonic (memory device) (e.g. '*righty-tighty, lefty-loosey*' for un/tightening a mechanism).
- Using a metaphor to explain the use of the control (e.g. twisting a key to un/lock, a light switch to signal on/off states).
- Connection to a similar, more widely used control (e.g. convention on a car seat or forklift)

Discoverability

To encourage discovery and use of the controls, as based on the requirements list, the controls of the office chair should be found without having to look for or stand up to search for the controls. This aspect is similar to the *visibility* guideline by Norman (1989). It targets not only the initial 'search' phase defined by Helander et al. (1995) but encourages the discovery of controls without explicit searching for the, inviting the user to try out controls.

- It is made clear through shape, placement and use of material that the control is an interactive part of the chair, not a structural component.
- The controls should be reachable by hand from a sitting position.
- The controls should be distributed over a limited number of 'hot spots' that users typically reach towards when searching for controls. These are the right and left side of the seat, to an extent the front and back of the seat and the armrests for armrest controls.

Feedback

It is important that the controls provide actuation feedback, so users are aware that the control was activated. Further, they should receive feedback on how far the setting was changed.

- When interacting with a control, information about what the control affects in the chair should be immediately identifiable.
- Points of reference should be given to the user as to improve the accuracy in the setup of the chair; including where the max. or min. is and how far the setting has been adjusted.

Constraints

How many use options the control has.

- The controls should only require one interaction to activate each setting, e.g. pressing and pulling upwards in one movement to move the armrest up instead of pressing to activate one button and then having to shift the hand position for dragging up.
- A control should only affect one setting since multiple functions for a control make it difficult to discern between them and understand how to actuate it.

Mapping

The layout and placement of the controls on the chair, relative to a user's position.

- Where a user would naturally touch and move the corresponding part, or
- Closest to mechanism activating it while within reach of the user from a sitting position.

Consistency

The use placement, movement and design of the controls should follow one discernible pattern throughout the whole design.

- The controls' base position or central axis is fixed in relation to the chair when not in use. An exception is for controls that are able to move from a position as long as it references a position that the control adjusts is in. For instance, the armrest control moves up if the armrest moves up.

- Communicate the controls as part of a whole. While optimised for individual demands of each setting, they should be consistent with each other in terms of the form language, colour, material and finish.

Affordance

The clues it gives on how it works.

- The controls should be different enough from one another to be discernible and not mistaken for another regardless of the position on the chair.
- The movement of the control should be perpendicular to the position of the fingertips when holding the control.

Friction

The ease of user of the controls.

- The settings should be adjustable in the shortest amount of time.

4.8.2. Applicability to other domains

The guidelines went into detail regarding how to design controls for improving use and user experience of controls on an office chair. However, the aspects outlined are similar to, and in part adapted from, existing principles of product design. In principle, these guidelines are applicable to the design of any set of controls used in a context where ease of use plays an important role. This includes the design for similar independent seating such as a wheelchair, or a chair that is adjusted in an integrated cockpit setting for instance, in a car or in a driving cabin for other vehicles. Reaching wider, they could be applied to strollers, walking aids, bicycles, scooters or similar products that require use of controls for adjustment.

4.9. Ullmanstolen Updated

This section presents the result of the redesign, first describing the shape changes and intent behind them, the new colour and material choices and then detailing the placement, use and semantics of the individual controls. First the complete concept for the redesign is described, with further elaboration on the colour and material choices below. The control solutions describe the complete semantic concept, from placement to usage metaphor and the expression of that metaphor through shape.



Figure 44, Render of the updated Ullmanstolen design

4.9.1. Aesthetic Concept of the Updated Chair

Minimal changes were made to the general shape of the chair for it to still be identifiable as the Ullman chair - the intention was to keep the connection to its unique features, which are tied to the chair's ergonomic aspects. This includes the cut-off at the front of the seat, the slanted seating area and slim backrest allowing better freedom of movement.

Addressing feedback from the user study and comparison with the current market, the shape was designed to be more soft- and comfortable-looking by rounding the corners of the chair's silhouette. The original sharp silhouette gave the chair a distinct 80s/90s look that was perceived as outdated and uncomfortable in the user study. In the updated concept, adding chamfers on the non-interactive parts at the backside of the backrest and the bottom of the seat and armrests to contrast with the rounded silhouette provides points of interest and detailing, tying back to the sharper transitions on the original chair. The armrest was adapted to branch out of the armrest body upwards to connect to the top of the armrest, which adds to a softer look that visually integrates the armrest with the rest of the chair. The profile of the armrest attachment was changed from a rectangular profile to a pill shape, slightly softening the shape while keeping the simple look of the chair intact. The armrest top in contrast was designed to be sharper and



larger compared to the very rounded original shape (a standard component and not part of the original design), to create cohesion with the rest of the chair as well as balancing the proportions. The design of the neck cushion was kept the same, adding a contrast both in shape and colour that grounds the design of the high and light-coloured backrest and ties it to the chair. Coloured accents are added to the controls for improved visibility among other factors that will be further discussed in the control subchapter.

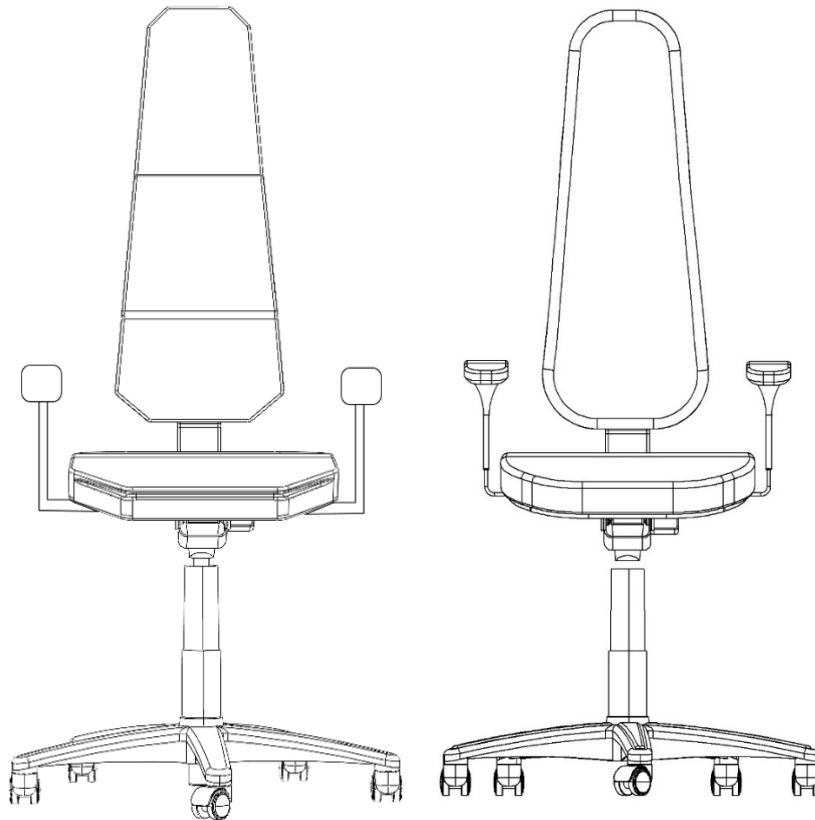


Figure 45, Comparison of the technical drawings of the original and updated Ullmanstolen

4.9.2. The Controls

The main focus of redesigning the controls concerns usability aspects, which are supported by their gestalt as a whole. Since they are part of a chair concept, they are designed to fit with the rest of the product while communicating that they are parts to be used. Coloured accents are added to signal the existence of the controls and separate them visually from the chair, while also adding a point of interest. Having a contrasting colour creates a metaphor associating with work tools, which often use one signal colour, and uses this tool metaphor to ask people to touch and use the control. The impression when looking at the control should not be that of a tool foremost, but rather a supporting part of the chair, so the colour and weight of the accent were kept small. The clustering of controls has been adapted to adhere to the design guideline relating to natural mapping (Figure 49). As can be seen between Figure and Figure the updated version's controls show more consistent clustering with limited placement 'hotspots' and increased symmetry of the controls. Placing the controls at the sides with lesser variations improves guessability of where controls are located as well as the ability to identify them from a

seated position. The proximity of controls also minimizes the effort required of users to test out other controls. Further, the different shapes of the controls facilitate unique movement (as will be described shortly). This aims to further improve guessability, and thereby the understanding of which control it is and ease in learning how to use it. In the same vein, the separate shapes and movements create a distinction that should minimize confusion and maximize the confidence that users feel while adapting the settings.

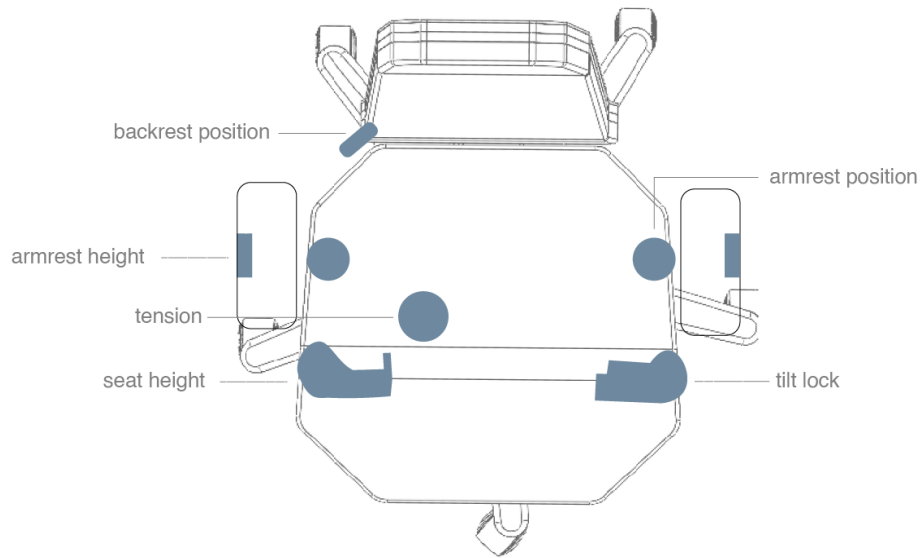


Figure 46, Original layout of Ullmanstolen's controls

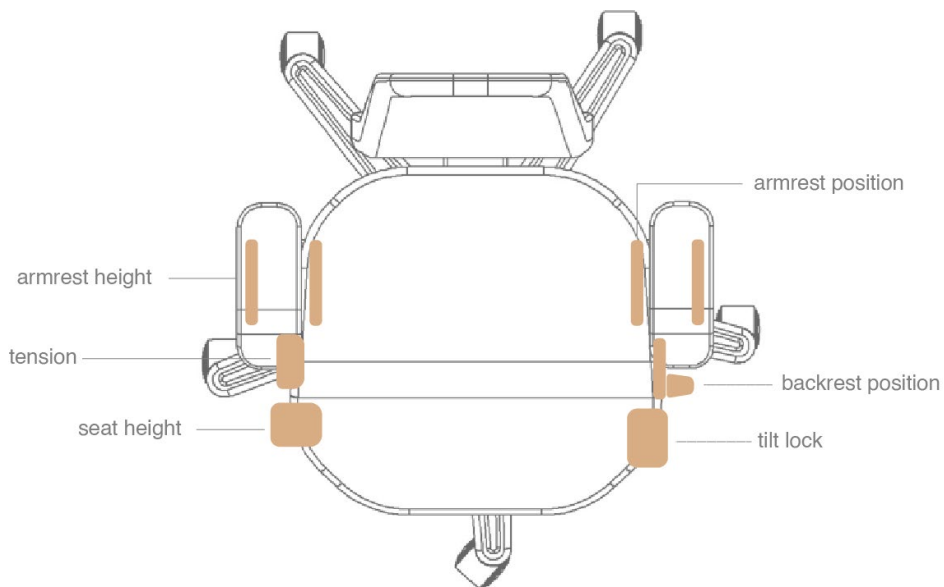


Figure 47, Updated layout of Ullmanstolen's controls



Figure 48, Right side of the redesigned Ullmanstolen, showing the left armrest height, right armrest width, tension and seat height controls (top left to bottom right)



Figure 49, left side of the redesigned Ullmanstolen, showing the tilt lock, seat position, left armrest width and left armrest height controls (bottom left to top right)



Seat Height Control



Figure 50, Illustrated upwards movement of the seat height control

As confirmed in the literature and conducted studies, the seat height placed at the front right side underneath the chair's seat is ideal in terms of recognition and guessability and was thus not changed. It is used by raising the control up to activate the gas spring pushing the seat upwards and pushing it down through body weight. Placed on a stick the control is slightly visible when looking down and provides space for the up/down movement. The seat height is shaped similar to the chair's seat itself, as a bent rectangle with cut-off corners to create an octagonal profile. The shorter side from the bend is placed to point outwards perpendicular to the seat with a slight downward slant to prevent slipping and afford better grip for the hand when pulling up. This shape adheres to the convention of the seat height control being a rather flat surface with enough grip for the flat of the fingers to pull upwards with, while relating to one of the chair's integral shapes.

Seat Position Control



Figure 51, Illustrated sliding movement of the seat position control

The mechanism to change the distance between seat and backrest moves the backrest instead of the seat, same as the original Ullmanstolen. The control is placed on the left side of the seat, opposite to the tension. It is a forward/backward slider that directly translates into movement of the backrest forwards and backwards with a close to 1:1 translation so the user receives immediate feedback on the actuation of the control from a sitting position when they lean against the backrest. Coloured haptic position indicators are placed on the base of the control, with distance between the indicator lines suggesting the distance of seat and backrest. The interactive sliding part of the control is pill-shaped and widening towards the base with a slightly concave transition between the top and base to provide better grip for the fingers to push and pull the slider with. The pill-shape is repeated from the metal armrest base and further indicates that the sides of the control afford the actuation movement, not the top or bottom. The widening base with curved transition surfaces creates a softer look compared to a straight extrusion that is offset by the chamfered front detail that is a part of the semantic concept of the chair.



Tension Control

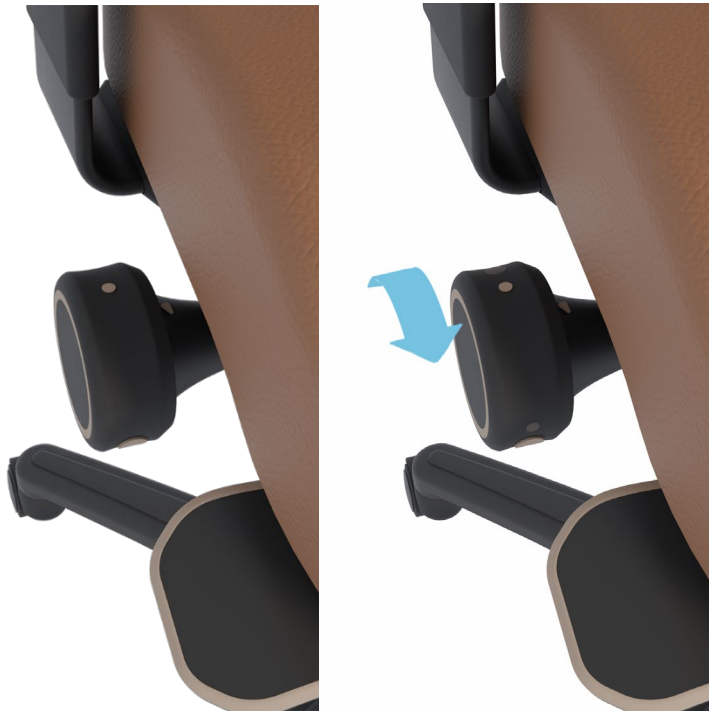


Figure 52, Illustrated rotation of the tension control

Following the common mnemonic, or memory aid, 'righty-tighty, lefty-loosey' that describes a universal design principle, the backrest rotation should 'loosen' the tension when turning left and tighten when turning right. Since the rotational axis is perpendicular to the seat, it makes more sense to have the control placed on the right because there is a) a larger chance to find it on the right since the seat height is placed there, indicating a location for controls and b) tightening - turning right - corresponds to a forward turn, which will cause the chair backrest being more upright, or leaning forward and a loosening, turning backwards, corresponding to the backrest leaning further back when weight is applied.

This turning motion is facilitated by a short cylindrical control shape. The circular part, also with a concave transition between the top and bottom of the cylinder, affords grip of the control between the palm and flat of the fingers to rotate with the wrist. On the transition surface dots in increasing size are placed to indicate by touch how tight or loose the control is currently set. These indicators are made visible through colour as well. The outside edge of the cylinder is chamfered, with another visual accent placed on the flat of the control, and the inside edge rounded.



Tilt Lock Control



Figure 53, Illustrated switch movement of the tilt lock control

The tilt lock is placed on the left side of the seat, at the front and high up towards the bottom of the seat, which limits access to the control from the top and nudges users to use it from the bottom. It is activated by pushing the side pointing away from the seat up towards it. The metaphor of this control is tied to a key in a lock or a light switch with an on-off setting, referencing the binary lock-unlock setting of the tilt lock with two set positions and no incremental movement in between. This was chosen over a rotation control, which also mimics a key unlocking because of the similarity to the tension and lack of a visual indicator of where the 'key' turns or how is stopped in its movement compared to the switch, which is limited by the bottom of the seat. With the tilt lock placed on the left the association between tension and tilt lock is broken, for the sake of better usability of the tension control. Since the seat position is also placed on the left side of the seat, the discoverability of the tilt lock is not significantly hurt. The control is a rectangular shape bent in the centre to form two 'wings' that are always placed out of balance to nudge the user to push the side unaligned with the seat base upwards. This motion is suggested by the rounded bottom of the control providing a more organic feel to touch with the fingers, whereas the top of the control keeps two flat sides to each align with the bottom of the seat. The visual indicator is placed on the chamfered outside part of the control, pointing away from the chair and slightly visible from above due to the angle of the chamfer.



Armrest Height Control

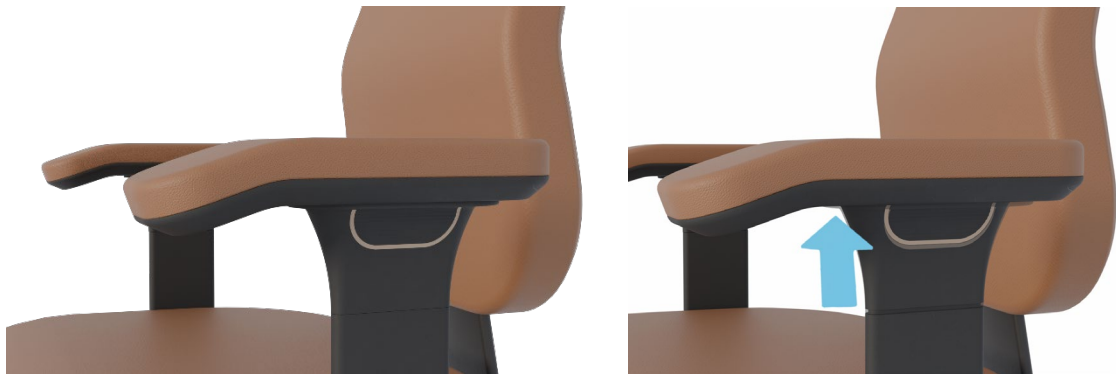


Figure 54, Illustrated upward movement of the armrest height control

The armrest height is commonly placed on the armrest itself, closest to the part it moves. The control position is kept on the armrest but changed slightly from the user test, where it was placed underneath the front part of the armrest. It was changed to the outside of the armrest just below the top the arms are placed on. There the control has the largest visibility and is easy to reach and intuitive to use by pulling upwards. It is activated by pulling the bottom of the armrest 'top' upwards, simply dragging up or down to the desired height.

Since it is fully integrated with the armrest, it offers the least distinction and visibility as a control. The whole slider has a pill-shaped profile encasing the metal armrest structure leading up and out into the underside of the armrest top. It does adhere to the natural mapping, as shown in the user test, in which users reached to pull up the armrests instead of searching for a control elsewhere. The actuation space - the space the control moves upward in before the mechanism is changed - is not fully hidden in the armrests underside to provide some visual clues. To further support guessability, haptic and visual indicators are placed at the intended area of activation. More space for finger placement is provided on the outside of the armrest, though the activation functions all around the underside of the armrest top.

Armrest Width Control



Figure 55, Illustrated outward sliding movement of the armrest width control



The armrest position was initially intended to move the armrests both forward/backward and further out from the chair. The design of the corresponding control caused a lot of confusion and after evaluation of the user study, it was decided that moving the armrests forward/backward along the seat, which was not part of the original Ullmanstolen configurability, was not needed. Larger armrests provide adequate support. Taller users are also likely going to position the backrest further away from the seat, simultaneously increasing the distance between shoulders and the armrests. It is positioned underneath the seat, attached to the armrest, where users are able to naturally grab the control to pull the armrest outwards or push them back in. The control is shaped to have a ledge for easy grabbing and sliding out along the armrest structure for the short actuation distance, leading into a movement sliding the whole armrest outwards. For pushing them back in, the control's ledge is grabbed with the fingers while the thumb, palm of the hand or whole arm is used to push the armrest in while the mechanism is activated, the same way the armrest height control functions.

The profile of the armrest width control is pill-shaped, encasing the structure of the armrest in the same design as the armrest height. Due to the placement on the underside of the seat, it is the least accessible control, being furthest to reach with the hands and without visual indication from a seated position. Therefore a large ledge provides grip for the fingers. Its soft transition out from the structural part with a cut-off where the fingers are placed provide distinction from the chair structure to indicate that it is a control. A texture and coloured indicators further afford touch of the control. Considering that the structural components on the underside of the seat are metal, the material and surface texture provide further indication. The control is attached to the armrest and placed behind two other controls on each side, providing very consistent mapping. However, the control has to shift outwards with changing armrest width and therefore cannot be placed in line with the other controls along the seat edge. With the outer, chamfered edge of the control sporting colour, another indicator is placed closer to the outer edge of the seat.

4.9.3. Colour and Material Choices

The updated chair strives for a softer, quality look to represent its value in a modern environment and still appeal to the more specialised target group. Considering the chair's time on the market, it can be considered a classic and benefits from a more timeless aesthetic, both in terms of shape and materials.

The structural components of the chair are made from steel to improve build quality and stability. Additionally, the steel is surface treated to give a cast iron look, a material that also has associations with long-lasting and quality. The housing mechanisms of the controls are made from polypropylene, a plastic common in furniture applications, which was the most suitable material when evaluating it with the parameters used in Granta shown in appendix V. The polypropylene chosen is matte with a slightly coarse texture to match the main body and to allow grip and hide imperfections that might occur while using the product. The upholstery materials proposed are leather, signifying quality and durability and tightly woven fabric, providing elegant quality with a modern touch. They are used on the main body of the chair,



consisting of backrest, headrest and seat, as well as the top of the armrests. Chamfers are added to the chair to add details to the chair which it loses with the overall softening of the chair's edges. Visible double flat stitching (see Figure 58) is used to emphasise the sharper transitions at the edges away from the areas affording touch.

Figure 56, *Stitching detailing on the chair*

Proposal of

Colourways

The chair concept proposes two material selections and two colourways. As a result of the material exploration, general colours to the leather version and fabric versions were picked. The colours chosen were created to be able to fit in multiple environments as well as match with each other to give a cohesive look to the chair line-up.



Figure 57, *A dark and a light concept for Ullmanstolen*

On the metal and plastic parts of the chair, black is chosen as a neutral base colour with connotations of stability and solidity. The majority of those parts are standard components and most likely will be black as a default (P. Ullman, personal communication, n.d.). Since not only the structural components but then also the controls blend into the environment, an accent colour is placed on the edges of the controls and on indicator symbols to signal to the user that these areas are of interest to them and invite the eye and to touch. Two colourways are proposed, one in a darker tone with a neutral accent and another, more modern choice with a pop of colour on the accent.





Figure 58, The two colourways for the updated Ullmanstolen: 8500-N, 6030-Y50, 1515-Y20 & 8500-N, 2020-Y50, 4020-B (left to right, based on NCS but represented by Hex codes in the thesis)

The darker version of the chair uses a rich brown colour that contrasts the black structural components. The black headrest links to the controls as well as creating visual separation to the chair body, emphasising it as a defining feature of the Ullman chair. The accent is a cream colour that matches with the brown. It is a subtle choice that does not demand as much attention, and is a more ‘classic’, timeless choice. The modern colourway changes the colour of the seat and the accent colour on the controls. The upholstery material uses a saturated beige and brings a lighter appearance to the chair, making it match the brighter home and work offices (seen in the mood board in Figure 31), which can also be considered a more day-to-day style. The accent on the modern version is a complimentary blue. As the seat is already bright and brings focus, using colour balances the attention. This palette suggests a soft, comfortable look, representing a new chapter.



Figure 59, Accents for the light and dark colourway

Material Choices



Figure 60, Fabric samples representing a range of fabric colours for the chair. From Ludvig Svensson (2022).



The upholstery materials chosen for Ullmanstolen are leather and woven fabric.

The fabric choice is Rami from Ludvig Svensson (2022) as it is made from natural materials that matches the chosen colourway. The textile is made from wool and ramie, a material that is known as one of the oldest fibres used in history. The wool material also has a long lasting, premium and natural association creating a strong link between the textile and leather material. Ramie and wool blend are also antibacterial, flame retardant, moisture absorbing and has a Martindale of 70 000 which makes them very abrasion resistant and be able to be used for a long time. The combination of yarns creates an irregular surface and colour tone which hides the wear that occurs over time (Ludvig Svensson, 2022). A third green colour for the colour way of the light version was picked as it fits in between the beige and blue in the colour wheel serving as a transition colour between the two.

As real leather is a classic, organic material, it carries the connotation of a high-quality product, whereas the fabric represents a more modern, day-to-day choice with a different level of comfort. Full grain leather is proposed as one of the materials, for its high quality and durability. The most durable leather type is approximated to be full grain followed by top grain, which is often sanded to remove imperfections. Some manufacturers (Kinnarps, 2024) use a semi-aniline process to protect top grain leather after sanding. This process adds a coating of pigment and a light protective layer that helps to hide scratches and imperfections that occur during use (Castlery, 2024).

4.10. Validation with a Physical Prototype

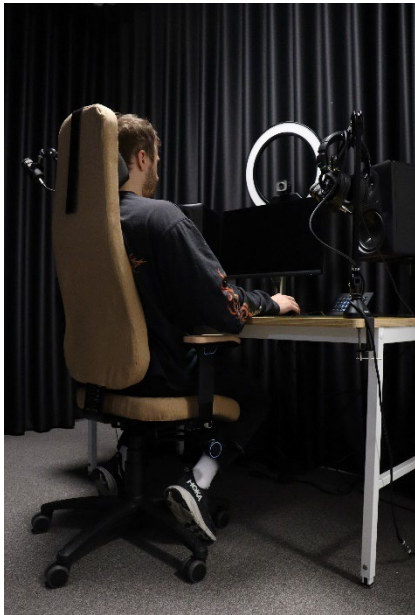


Figure 61, The prototype in use.

Lastly, a physical prototype was built to showcase the redesign and further test whether the design of the controls was suitable. The three usability requirements evaluated are reachability from a sitting position, discoverability without looking, and usable visual indicators of the control's setting. The prototypes turned out well overall. All controls fit well into the hands, with affordances and small haptic features such as texture on the actuation area to guide use. They were visible from a seated position, with the coloured accents indicating them as controls. Most importantly, they were all reachable when seated without much movement required. Some room for improvement was still found – mainly with the backrest position. Its small size fits comfortably between the thumb and forefinger, but the pinching motion required to move the control is not ideal, as it provides too little grip with higher resistance from the mechanism. The sliding motion is an intuitive, direct association with moving the backrest back and forth but the design should be improved for ease of use. The full functionality of the controls could not be evaluated with this prototype as they were not connected to working mechanisms.



Figure 62, The full prototype of the updated Ullmanstolen.





Figure 63 & Figure 64, Seat height and seat position controls in use



Figure 65 & Figure 66, Tension and tilt lock controls in use



Figure 67 & Figure 68, Armrest height and armrest width controls in use



5. Discussion

The aim of the thesis was to investigate the use of office chair controls, specifically how they are understood and what that understanding is shaped by, both in terms of functionality and aesthetics. The focus of the work was on Ullmanstolen, researching the user experience of the office chair, developing a guide for improving usability and reflecting the findings in an updated design of the chair. The research questions were split into investigating the understanding of the controls and resulting design guidelines and reforming the appeal of the chair to suit the current customer.

5.1. Research Question 1

What shapes a user's understanding of the controls of Ullmanstolen and other chairs? How can this guide the design of the controls to be more intuitive?

Some environmental factors influencing understanding in general are the context an office chair is used in, for example how frequently a user sits in the same chair, as well as the individual user's previous knowledge and training received and frequency with which they use a control. Further, cultural differences are influencing factors. Within the context of shared offices, learning the use of controls is a lesser factor and in the long term, as shown in the literature study, controls are not adjusted frequently enough to achieve significant learning over time. Most users do not actively engage with the controls when sitting down as they are secondary to the goal of getting work done. Therefore, better design and placement present larger influencing factors on how well office chair controls are understood.

Since user learning cannot be relied on, improving the guessability on first time use improves the overall setup experience both short- and long-term. To achieve this, metaphors can be used to match user expectations. Even considering differing environmental and individual factors, there are shared previous experiences they relate to. These mental models are able to guide the control design to create more intuitive use - by supporting the subconscious ways in which people find and try to actuate the controls and using constraints, consistent placement and affordances to further guide use even when the users are unfamiliar with the control. Not only consistent placement is important, but also placement where the user naturally reaches towards. Along with this, more guiding principles are providing good visibility and accessibility of the controls from a seated position, differentiation from the structural chair components and distinct features from each other in use, clear direction of the intended movement and clear feedback on actuation.

The understanding of Ullmanstolen's controls was found to be poor, with more visual indicators as well as more differentiation between controls desired. The placement of some controls too close to the mechanisms below the seat and therefore not within reach or sight of the user led to them not being adjusted or little adjustment where the changes made were not understood due to a lack of indicators or any significant change in settings occurring. To improve the use and

accessibility of Ullmanstolen's controls, the mentioned guidelines were considered in the redesign. Functionality of the controls was changed to provide easier access and immediate feedback on actuation as well as improved grip affordances that signal the intended way to use a control. Colour and texture provide further indication. Since research has suggested that people distinguish aesthetic factors better than functional ones, the controls were designed to offer visual and haptic cues on their use through colour and texture while following one semantic concept with the rest of the chair.

5.2. Research Question 2

How can Ullmanstolen's unique features be emphasised while appealing to current user preferences?

The redesign regards both functional and aesthetic aspects. The functional aspects centre the layout of the controls, optimised for easy use and understanding, with a focus on guessability and to an extent learnability (Jordan, 2002) while the aesthetic changes concern communication of the chair to the user. This includes appeal to the current target audience, market positioning and comfort among others as users interviewed have expressed that the chair looks dated and uncomfortable compared to current chairs. The function analysis and list of requirements helped distil the intent behind the original design beyond what it looks or feels like in use. Even when changing large aspects of the design, such as the control's shape and layout or the number of controls, keeping the intent of the chair's functions intact communicates that it is the same chair, only updated. The distinct features of Ullmanstolen are the high, narrow backrest, slanted and cut-off seat and access to controls that allow adaptation to each user's body and encourage active sitting by changing between the many seated positions possible on the chair. The first two are ergonomic features that are expressed visually with a unique shape. Changing these aspects changes the character of the chair, so care has been taken to maintain its recognisability as Ullmanstolen. When updating the form language of the chair, these aspects were kept while the overall design was adapted to become softer and look more inviting by introducing rounded features. The angled cuts introduced to offset the soft edges recalls the sharp corners of the original design. The availability of many controls on the other hand is a functional feature. Making those more accessible and usable improves this feature of the chair, even with a changed layout because the layout is not the defining function of the controls. Besides the key feature of the chair providing ergonomic support, it is designed for simplicity, allowing visibility of and easy access to the chair's construction. These characteristics were also preserved in the controls' designs, not hiding the mechanisms and placing them in easily visible places as well as not introducing easily breakable components or fragile materials.

5.3. Result Discussion

There are two main outcomes of this project: a set of guidelines that were established drawing from research insights and existing design principles, and an update of the chair this work

focused on, Ullmanstolen, that aims to improve intuitive usability, leading to more a more comfortable and ergonomic use of the chair.

5.3.1. Design Guidelines

The guidelines are a distillation of the research and studies conducted throughout this thesis that are adapted from established design principles. The conclusions drawn follow existing principles and research, which was confirmed throughout the process, only adapted to the more specific use case of office chairs and office chair controls. A large part of the research findings was that there is very little standard and cohesion on the market when it comes to office chair settings, even within the same brand, which limits learning, creates confusion in users and presents a part of the problem of users not setting the chair to their ergonomic needs, which may lead to bad posture and health issues beyond an uncomfortable sitting experience. Establishing these guidelines presents a push for standardisation, if not of the specific gestalt of the controls, then at least in the way they are presented to and respond to the user. The focus of the guidelines was first and foremost intuitive use and communication of intent to the users. The guidelines are framed within the context of an office chair, specifically with the intent to update Ullmanstolen. However, the principles that can be extrapolated could be adapted to other types of controls. An interesting aspect of these guides is that they may be in conflict with one another in some cases, so a discussion can be had on weighting and ranking the guidelines or establishing a trade-off system. Generally, the designer has a lot of freedom and thereby responsibility to make these judgments based on intuition but also by incorporating the user more throughout the design process.

5.3.2. Updated Ullmanstolen

There were many controls to consider, all with differing movements, placements, mental models associated and more, which became a large task in the process. Throughout the project, certain controls became the focus, especially the ones users struggled with. There was also variation in the level of description of the controls found in the literature. The armrest position for instance was often not concretely defined. Some controls, such as the tilt lock, would have needed an extra user test due to its novelty and lack of familiarity with it on the user's side. All this led to variation in the feedback on and knowledge about the different controls. Further tests would also have to be done on the seat position control as the final design concept was not tested by users other than ourselves.

Concepts weighed in the decision matrix may be re-evaluated through a user test instead of basing it on the weighting in the requirement list, as there was not a clear 'correct' decision with a small discrepancy between two of the controls in both matrices. Further, users during the study and test were found to have very different frameworks and preferences for using the chair, which led to large variations in the results that would most likely continue in a larger sample size. Therefore prototyping results may always be dependent on the participant demographic. In the prototype, not all controls used markings to indicate their relative position when in use, as the controls were not fully functional. For instance, having markings indicating the armrest height is desirable.

There is also a discussion to be had about the material choice. Using leather for the upholstery may not be an ideal material for use in an office chair, as the material is less breathable and may become hot and uncomfortable to sit in. But as the leather material signals quality and a long-lasting product with history, the material was still chosen for one version. In the headrest leather was still preferred as it is in contact with the head and scalp, where a fabric headrest may become greasy and unappealing over time. This sentiment was affirmed in the research where the old textile headrest was perceived as unattractive by people. On the other hand, keeping durability in mind and offering the upholstery of the chair to be washable by users, a textile headrest could be chosen, provided it is both a durable and washable fabric.

5.4. Recommendation for future development

The user study and testing were done on a relatively small scale and showed large differences in previous knowledge, understanding and preferences. Since the target group for office chairs is close to a general sample of the population, there are many influencing factors, as was shown in the literature review as well. Doing an evaluation of both functionality and aesthetics, for instance by another user test and a semantic evaluation would be recommended. For this a full prototype with high fidelity controls needs to be built, at least with controls that represent the haptic feedback accurately, if not the full functionality. To assess the suitability for the current market in a further step, a comparative study with other office chairs could be done.

5.5. Process Discussion

In this section, reflections are made on specific points in the process and the rigour and validity of the results.

Double diamond

Working with the double diamond was a great contributor in the creating of the structure for the thesis, dividing the work into phases helped in picking what methods should be used and where. Although the double diamond is minimal with two diverging and converging phases the basic structure of it makes it easy to adapt to the needs of the project.

Benchmarking

In the benchmarking there were often discrepancies between controls on chairs seen in stores or at the fair compared to the controls listed and visible on the brands' online stores or instruction manuals. For the same model of chair, for different chair configurations or production years the type of controls on the chairs sometimes changed and there was no consistent identifier of the exact chair documented, such as a serial number. This, along with widely varying types of controls, even across editions and models of the same chair series, made an impactful quantitative analysis more difficult. It also highlighted the lack of a standard in the industry.

User Study

It should be noted that the majority of people that tested the Ullman chair were asked to sit in the chair within the context of this study, with the exception of the long-term user. That may have skewed the results towards higher curiosity than is typical, reflected in a higher use of the controls. On the other hand, over the short term, comfort was less of an issue, leading to some users not feeling the need to change the controls. The main users used the chair on only one occasion for limited time, which did not allow them to become completely accustomed to the chair, a factor that is especially relevant for Ullmanstolen with its atypical seating design. Moreover, the perceived comfort of the chair is affected by the correct adjustment to the person and therefore influenced since those settings were determined by the previous user. To create a complete comparison of the comfort of the chair, it needs to be set to each user and then an evaluation could be done with subjective opinions as a marker, together with objective results from variations in sitting posture of the participants. Or, deliberately setting up the chairs as uncomfortable to each person could have been a good option to evaluate the controls and the setup experience, nudging people to try out the controls since a chair that was set up by one person might have been comfortable to another person and might not have given users a reason to change the controls.

The sitting environment also differed between the survey and interviews, between an office desk and a coworking space with users working on laptops on low tables, causing differing posture. When placed with the other office chairs present during the observation, it was also clearly the odd one out due to its shape, leading users to sit in it less frequently when not asked to. Within the context of this thesis the variations provided a richer qualitative perspective but lessened the rigour of the study.

User Test

The user test was framed as a validation of the initial design and layout of the controls. Instead, engaging the user earlier in the process and encouraging participation through a co-creation workshop may have given a deeper look into their frame of reference. However, with the volume of controls and options for design and placement, a more extensive cycle of ideation and testing with ideally a larger user group would have been necessary.

Materials and Manufacturing

The material section of this report represents a suggestion of a material choice as manufacturing was not a part of the scope for the report. Therefore, the choice of material was foremost involving the aesthetics and what that material would convey to the user to resolve the major complaint that the chair looked uncomfortable. Further testing of what type of textures, material and colours that users prefer could therefore be done. As the creation of the control prototypes used 3D printing, active thoughts about manufacturability were not needed more than being able to assemble the parts together for the mock-up.

In the final two concepts, the dark and light version, there is one accent colour each for the controls which would require separate manufacturing for each of the SKUs (stock keeping units). Either in the primary process in the use of insert moulding or in post processing, adding the colours afterwards. A comparison between these alternatives in production and an analysis of how expensive it is having two variations must be done.

5.5.1. Ethical Considerations

Since the research and testing phases involved other people as users, care was taken to involve them in an ethical way. Interviewees, participants of the user study and prototype test were informed of the project, asked for consent with regards to recording them and informed on how the data collected was going to be used. The data was anonymised, with only necessary information collected - for example documenting only the relation to design work rather than noting down the specific job. In terms of the ethics of the design, the health of office work was considered, researching postures and accessibility in design, though the norms associated with sitting for extended periods were not questioned within this work.

5.5.2. Sustainability Considerations

In many aspects of the thesis, not changing unnecessary components played into sustainability, both environmental and social. The design of an ergonomic chair aims to create a positive impact on human health and safety and care was taken during the project to keep the ergonomic features intact. The product life of the chair was extremely long to begin with, with long-time users having had it for ten or more years. Therefore, care was taken to not introduce components or materials that are easily breakable or have a rapidly changing state of the art, such as electronics. The simple design and design for disassembly philosophy of Ullmanstolen was kept in mind as well. In further steps research could be done on the environmental impact of the upholstery material and designing the controls in the most material- and manufacturing-efficient way.

5.5.3. Use of AI

AI tools were used to a limited extent over the course of the thesis. For transcribing interviews with users, only the university-approved software was used for data privacy reasons. Image generation tools were used during the process for the generation of mood boards and inspirational mock-up images based on concepts created during the thesis. None of the content of this thesis or the images included were created using AI. The use of these tools was discussed with the supervisor.

6. Conclusion

The goal of the thesis was to investigate what shapes a user's understanding of office chair controls and how this can guide the design of controls to become more intuitive, by focusing the research on a particular chair, Ullmanstolen. Furthermore it sets out to explore how Ullmanstolen's unique features can be emphasised while appealing to current user preferences, as the chair was originally released 1986. The conducted studies gave insights into the associations that shape user's understanding and actions, leading to a set of design guidelines translated into a redesign of the Ullman chair with the goal of creating more easily usable controls and thereby an improved sitting experience. The created guidelines can be used as reference when (re)designing a set of controls for an office chair to be more user-friendly or for other physical controls that are used infrequently and therefore provide challenges in usability. The redesign of Ullmanstolen proposes implementation of said guidelines to create a chair that is more intuitive and adapted to a modern context.

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Appendix

I. Mechanism Evaluation

A. Control Movements

Control Movements	
Rotational	Rotate (placement at side or back)
	Rotate (placement underneath)
	Twist
	Crank
Pulling	Pull up
	Pull out (spring)
	Pull out + Push In
	Pull out + twist
	Latch
	Snap (latch with spring)
Press (+ pull)	Press
	Press + Pull (placement underneath)
	Press + Pull (placement side)
	Squeeze
	Slider
	Pump
	Brute Force

B. List of Chair Models analysed

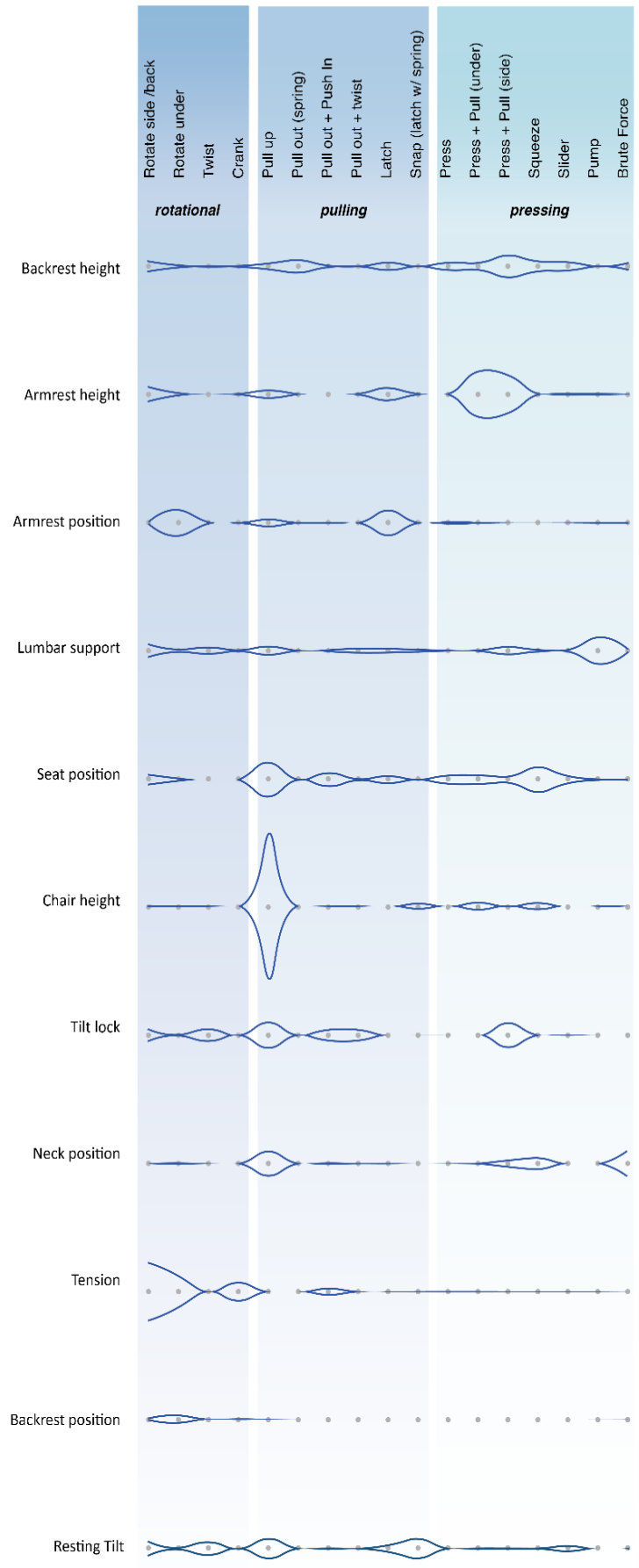
Brand	Model
Kinnarps	9000
Malmstolen	4000 classic
Malmstolen	Active R3
Herman Miller	Aeron
Herman Miller	Mirra 2
Herman Miller	Embody
Vitra	Eames EA 117
Vitra	Rookie
Lanab	LD6340
Lanab	Höganäs 280
Savo	Soul
Håg	Capisco

Håg	SoFi Mesh
RH	Logic 220 XL
RH	Mereo 220
Kenson	Anna
Ullman	Ullmanstolen
Humanscale	Freedom
Humanscale	Liberty task
Humanscale	Diffrient world
Humanscale	Path
Kab	<i>Unknown, integrated keyboard*</i>
Kab	ACS Executive
Kab	<i>Unknown, executive-like*</i>
Tronhill	Amadea Manager
Tronhill	Gabri Executive
Svenstol	S5

*These chairs did not match the configuration listed online in terms of mechanisms/chair design

C. Analysed mechanisms

The following graph presents a breakdown of the type of motion required to actuate each found mechanism was present on the chairs analysed during the benchmarking. The height of the line represents a higher number of chairs using the corresponding movement to actuate the control.



II. User Study

A. Interview Template

Notes: Have chair present to facilitate discussion.

General

Name:

Occupation:

Use setting/environment:

- How would you describe your level of interest in (office) chairs?

(Relevant background? Are they ergonomics researchers, designers, not related to chairs)

- What was your first impression of the chair? (Regarding aesthetics and comfort expectation)

Adjustment

- Could you tell us about your setup experience with the chair?
- Did it provide you with all the settings you expect in an office chair?
- What settings are those and what was missing?
- What difficulties did you have in adjusting the chair?
- When you found the controls, what functions did you expect them to fulfil?
 - And were those expectations matched?

(Please elaborate on the specific controls)

Comfort

- What was your perceived level of comfort compared to other (office) chairs?
- How were you sitting in the chair? (Different positions?)
 - Why?
- What would make the chair more comfortable?
- Did you experience any pain?

Aesthetics

- (Did the chair's looks match with your sitting experience?)

Comparison

If you regularly use a different office chair:

- What chair do you use? Do you like it?
- How does it differ from Ullmanstolen? Please compare positives and negatives

B. List of Participants

	<i>Occupation</i>	<i>Relevant background</i>	<i>Duration of use of Ullmanstolen</i>
Interviewee 1	Researcher	Design background	Half a day
Interviewee 2	Researcher	Upholstery background	A day
Interviewee 3	Researcher	No design background	A day
Interviewee 4	Researcher	Seating comfort researcher	During interview
Interviewee 5	Researcher	Design background	Half a day
Interviewee 6	Designer	Long-term user of Ullmanstolen	20 years

C. Survey

1. Which chair did you sit in? **



Just mark an oval.

- 1
- 2
- 3
- 4

2. How long did you sit in the chair? *

Just mark an oval.

- 30 minutes
- 30 minutes - 1 hour
- 1 - 3 hours
- more than 3 hours

3. Did you use any of the controls to adjust the settings? *

Just mark an oval.

- Yes Continue with question 4
 No No Continue with question 8

4. What settings did you change?

Select all the appropriate answers.

- Height
 Arm rest height
 Arm rest width
 Arm rest swivel
 Tilt lock/unlock
 Tilt tension
 Backrest distance
 Seat position
 Backrest height
 Switch backrest tilt angle
 Attach detach backrest and seat synchronization.
 Lumbar support

5. How easily did you discover the controls that you wanted to change?

Just mark an oval.

- 1 - I couldn't find the ones I was looking for
 2 - I had to search a lot.
 3 - I found what I needed after some searching
 4 - The controls were placed where I expected
 5 - I didn't even have to think about 'finding' them

6. How easy were the controls to adjust? *

Just mark an oval.

- | | | | | | | |
|-------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|------------|
| | 1 | 2 | 3 | 4 | 5 | |
| | | | | | 5 | |
| Diffi | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Easy peasy |

7. What did or didn't you like about the controls?

8. How comfortable was the chair? **

Just mark an oval.

- 1 - I would rather sit on a bus stop bench
- 2 - Works for a short time
- 3 - It's just like any other office chair
- 4 - I could work in it all day, no problem
- 5 - I could sleep in this

9. Which positions did you sit in? **



Select all the appropriate answers.

- A
- B
- C
- D
- E
- Other: _____

10. What would make the chair more comfortable for you?

11. Do you sometimes get pain from sitting in office chairs?

Just mark an oval.

- Yes
- No No

12. What pain do you experience? Why?

13. Would you be open to answering some more questions? Please leave your email.

D. Survey Results

The results marked in orange regard the use of Kinnarps chairs, all others have used Ullmanstolen. Answers to question 13 were not included for privacy reasons.

Timestamp	Which chair did you sit in?	How long did you sit in the chair?	Did you use any of the controls to adjust the settings?	What settings did you change?	How easily did you discover the controls that you wanted to change?	How easy were the controls to adjust?
1/29/2024 16:26:00		30 minutes - 1 hour	Yes	Height	1 - I couldn't find the ones I was looking for	1
2/20/2024 10:59:17	2	< 30 minutes	Yes	Height	4 - The controls were placed where I expected	4
1/24/2024 14:42:02		30 minutes - 1 hour	Yes	Height	4 - The controls were placed where I expected	3
1/30/2024 15:59:41		more than 3 hours	Yes	Height	4 - The controls were placed where I expected	4
2/14/2024 10:38:02	3	more than 3 hours	Yes	Height, Arm rest height, Arm rest swivel, Tilt look/unlock, Backrest height	3 - I found what I needed after some searching	4
2/9/2024 15:35:28	3	more than 3 hours	Yes	Height, Arm rest height, Arm rest width, Arm rest swivel, Tilt look/unlock, Tilt tension, Switch backrest tilt angle	4 - The controls were placed where I expected	4
1/30/2024 15:59:09		< 30 minutes	Yes	Height, Arm rest height, Arm rest width, Backrest distance	2 - I had to search a lot.	2
1/25/2024 11:55:27		1 - 3 hours	Yes	Height, Arm rest height, Tilt look/unlock	1 - I couldn't find the ones I was looking for	2
1/25/2024 10:39:22		1 - 3 hours	Yes	Height, Backrest distance	1 - I couldn't find the ones I was looking for	1
1/24/2024 14:12:58		< 30 minutes	Yes	Height, Tilt look/unlock	4 - The controls were placed where I expected	2
1/29/2024 11:38:18		1 - 3 hours	Yes	Height, Tilt look/unlock, Backrest distance	2 - I had to search a lot.	2
2/9/2024 15:34:21	4	more than 3 hours	Yes	Tilt tension	3 - I found what I needed after some searching	4
1/30/2024 10:49:50		30 minutes - 1 hour	No			
1/24/2024 13:29:55		30 minutes - 1 hour	No			
1/24/2024 17:50:50		30 minutes - 1 hour	Yes		1 - I couldn't find the ones I was looking for	1

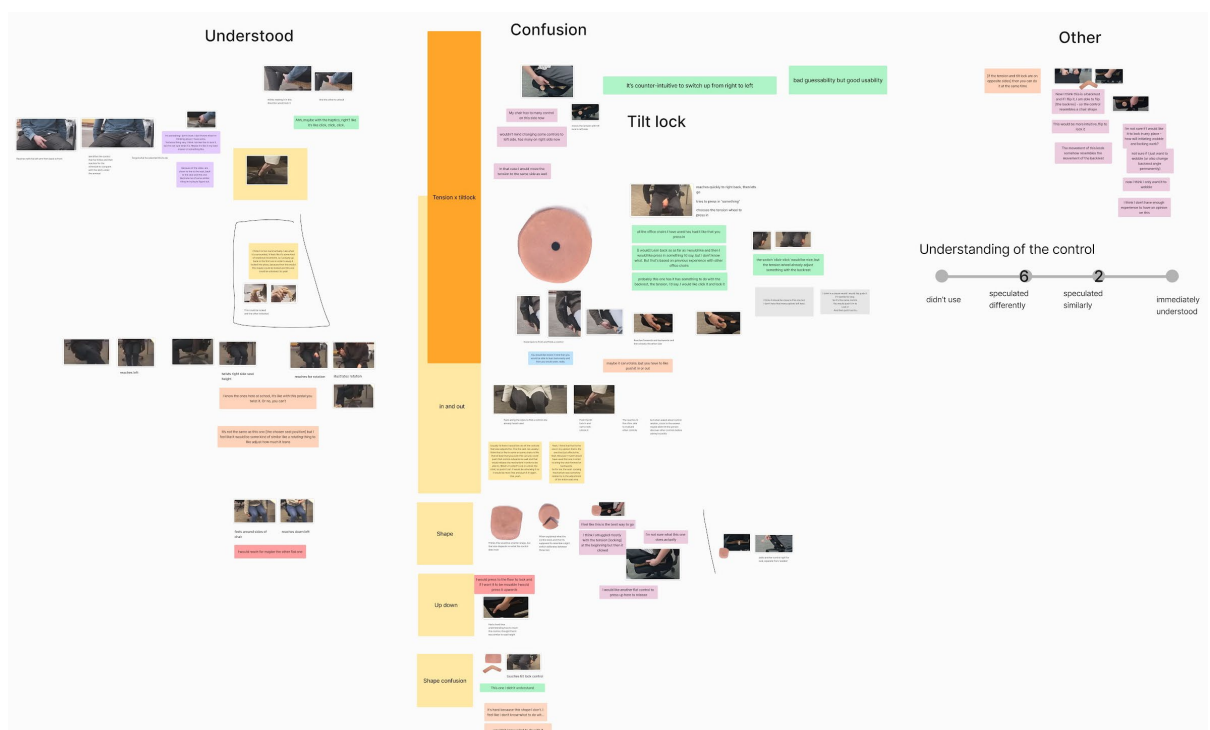
What did or didn't you like about the controls?	How comfortable was the chair?	Which positions did you sit in?	What would make the chair more comfortable for you?	Do you sometimes get pain from sitting in office chairs?	What pain do you experience? Why?
Difficult to understand. I was only able to figure out how to change height, gave up on the tilt. I don't know what the control on the left hand side is for since it doesn't move. The angle changes	3 - it's just like any other office chair	D	Softer support and being able to change tilt	No	
I felt like I found it by luck, the first lever I tested worked. But I think I couldn't guess what it does based on visuals. The left lever, for example, I do not understand what it does. I also changed one thing only, which is not the complicated.	2 - Works for a short time 3 - it's just like any other office chair	B, C A, B	Move neck support back Headrest was maybe a bit too pointy for the use case in which I used it. I looked down a bit when using the laptop, which made it feel pointy. Had I looked more forward it would've been more comfortable. The bottom of the headrest could maybe be more rounded. The chair in it self felt a bit stiff, which might make it uncomfortable during longer use.	No Yes	Mostly neck pain and lower back. Likely due to posture or long sitting sessions.
I liked that they didn't require a lot of effort to change, easy buttons to press and levers to pull. Would like to have the arm rest higher than is possible. And the head rest is a little bit loose as well, feels strange that they gave nice haptic feedback!	3 - it's just like any other office chair 4	B A, B	Lower, the lowest height is still not low enough Little bit softer cushions would be nice	Yes Yes	Neck and back because of lack of support of wrong support Stiff neck and shoulders. Sore legs
I had to get of the chair for most settings to understand where they were and how to adjust them, for all except the height of the chair and armrest. Also tilt did not function when I restes it. The controls for the armrests were tricky - rotation of the the control next to the rest itself (twist hands in an unnatural position) Liked the adjustable neck support even if the weight bounced into the back support when the chair tilted forward The other controls felt counterintuitive - don't know how to use them Nothing basically. The lever on the left did i not understand anything about. Pull, press, swivel nothing worked haha	4 - I could work in it all day, no problem 4 - I could work in it all day, no problem	A, C, D, E A, C, D, E	The chair is not too soft, liked the neck and back.	Yes	In the lower back - no support No pain but unpleasant for the knees sometimes
I found the tilt control difficult to use. I tried pushing it up or down but then had to pull it out and it didn't run very smoothly. I didn't really manage to set the chair in a comfortable tilt. Maybe I used the wrong one I still don't understand how I locked the back in a stable position. Also I could not make the chair low enough - though this setting was easy to understand.	4 - I could work in it all day, no problem 2 - Works for a short time 4 - I could work in it all day, no problem	C, D B A, B	The back is too narrow was feeling like I was slipping out. A bit too little lumbar support. The arm rests were way to short and I wanted to keep my elbows closer to my body but that was not possible. It tilted forward too much. I didn't feel like I could rest back against it. The pillow stuck into my neck a bit The headrest was a bit uncomfortable. The chair should be able to go lower, I am relatively short but still a normal height (165cm) and it was too high/tall for me. My arms ended up too high above the table and I leaned back (so that the back of the chair tilted) my feet didn't touch the ground Arm wresits and something for my feet	No Yes Yes	In my neck mostly from sitting with a bad posture/ looking at a screen Back pains, usually from lack of support in lower back
Hard To notice, a friend told me how to change it for me!	4 - I could work in it all day, no problem 3 - it's just like any other office chair	A, B B, C	Less annoying head rest, better support for lumbar spine, ability to lock positions in more angles than only straight up and smoother adjustment for the armrests The thing is that sure, the chair sucks when it comes to adjustments and so on. But if you would consider requirements in different hierarchies I would say that adjustments are not crucial after the point you have gotten the hang of them. Because it is not that often that you need to make big adjustments on your office chair, at least in my use of it The neck support was a bit too pointy and I would also prefer if it could not move sideways. I did not manage to regulate anything on the chair, it was difficult to figure out so I gave up- therefore it was not super comfortable Wider headrest, lowering height	No No	Back and neck pain
When I tried adjusting the height (left under seat is what I thought it would be at least) it felt "locked" and I couldn't make change that I wanted	2 - Works for a short time 3 - it's just like any other office chair	B Alternating between A,B,C		Yes Yes	Lower back and neck, I often tend to sit more relaxed with a cuned back and look down at the computer with a bad angle and not have the arm rest adjusted well to the table

III. User Test

A. List of Participants

#	Occupation related to desk work	Design/User Studies Background	Gender	Age	Height (cm)	Hand size (glove size)	Other Specifics
1	Yes	Hobby	Male	26	193	10 (large)	Right-handed
2	yes	No	Male	23	170	small	Right-handed
3	Yes	Yes	Male	24	180	10 (large)	Right-handed
4	Yes	Yes	Female	26	173	8	Right-handed
5	Yes	Yes	Female	24	162	Ca 7.5 (small)	Right-handed
6	Yes	Yes	Female	25	170	6-7	Right-handed
7	yes	yes	Male	24	187	10	Left-handed
8	Yes	No	Female	37	181	Large	Left-handed

B. KJ Analysis



Understood



First control reached for

usually more flat

I would grab one of those moon factor finishes down there and try to like press it up that the other one goes up

This one fits good

reached to right front

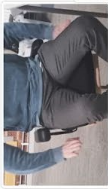


"a seat position is either more or less like it's go up or down seat I would try to find some kind of lever or something that I feel like has like an on/off switch, say this one."

"It's elementary, like the thing you want to do first on a chair, so it should be at the like easiest position to find"

"It's harder to reach like somewhere down here or that's further away so that's why I feel like [this position] the easiest thing"

Seat height



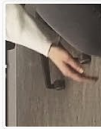
recently pulled it up, then hands on cupping motion, but also grabbed the control with the fingers

Here someone, move hands up and down through the sides

"I'd would like to lower the seat, I would just pull it up and let the gravity lower me. And if I want to raise the seat, I would push it up and yeah, stand off the chair for away and leave it alone."



They were looking for the right control



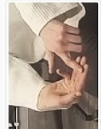
Participants couldn't find the right adjustment lever



Most participants found Figure 1 to be the most difficult to find when in control



Participant 10, who was the only one to adjust the seat



Confusion



They were looking for the right control

"I'd would grab that one up, the first control on the left side of the chair, and try to like press it up that the other one goes up"

"I'd would like to lower the seat, I would just pull it up and let the gravity lower me. And if I want to raise the seat, I would push it up and yeah, stand off the chair for away and leave it alone."

It's like usually like a flat kind of pedal that you push up and down. Or it might be that I'm used to that kind of chair



Comparison to the lever at the front of the chair



Participant 10, who was the only one to adjust the seat



Participant 10, who was the only one to adjust the seat

Other

could be changed with feet? Might not feel as intuitive



Participant 10, who was the only one to adjust the seat



Participant 10, who was the only one to adjust the seat



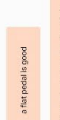
Participant 10, who was the only one to adjust the seat



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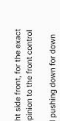
Participant 10, who was the only one to adjust the seat



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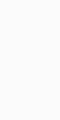
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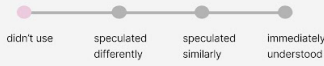
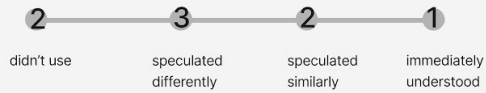


Participant 10, who was the only one to adjust the seat



Participant 10

Understanding of the control



tries different positions up on armrest - under side, left thumb, under front
doesn't want any control, prefers just moving with resistance



Maybe with some clicks - 1,2,3

Maybe I don't want to have a specific button to press for that - just with enough tension...

one movement at a time; want both armrests at exact same position so I...

would like a button on the side
still reached for the front control, but talked about something else - so found it but decided not to use it - shape is the issue?



Grabbes at the front and then to the side

Contradiction in what said want to push but grabbes the front and pull it forwards

Would like the same button to move backwards and forwards as well as in and out

Would like to be able to push it OK

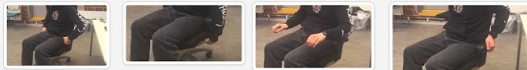
Would like like some kind of Lock so it doesn't Slide. So maybe yes, the button under

Yeah, since I wanted the other button here I think it should be like on the side. I think I would like the same button for all directions Otherwise it would be hard to find which button they switch.

Understanding of the control



chose controls under top of armrests and also gripped the sides of the top



grips under armrest top, to slide fwd/back

grips under armrest

illustrates sliding motion

grips sides, also for sliding

I would say that's like it's the same as with sliding [the seat].

I think I'd press here, upwards [refers to controls under top of armrest]

Oh yeah, you could have them on the side here as well, the same way. Just pressing up here.

I could imagine also clicking something here to drag them forward maybe? But that's like the that that's probability too. More options in my mind. Let's see.

Identifies the armrest height button and would press it inwards with thumb



I feel like this would kind of unlock the mobility of the entire armrest, so I can. Just move it around. Up and down or something like horizontally as well. Might be the ambitious, though I don't know.

chose the intended control, but did not understand the shape
• spinning?
• dragging it out?
Was perceived as angle



I don't know what to do with that angle. If I should spin it or drag

the control isn't telling me much

Understanding of the control



Would like to rotate the control and by that rotate the armrests or drag it out



Yeah, I think it would maybe use the same ones as down here, but instead of rotating them over. Like, either push them forward or push them backward. Yeah, I think that's that's right.



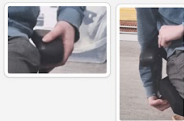
The left side with the height of the left

Grabbed this part when told to move the armrests in an out

I think that's actually where I would adjust it because that indicates the rotational point of the armrests like where they're mounted.

As the armrests can move in two directions and rotate, suggest that could place another mechanism here

Grabs top of the armrest from the sides first then reaches down to decide there



I would like to like if it was maybe these ones, I would like to Put it downwards And then put it, then adjust the the width of this and then put it upwards again.

Understanding of the control



unhook the control to pull in and out
felt control for width
for sliding fwd/back chose top of armrests to grip



You unhook something and then you can pull it in and. Out. And so like a similar that these [height change control] are, but maybe another shape.

Understanding of the control



indifferent to controls and position, should be located on the armrest itself at least



But I don't know how far up. Like it could be down here as well as up here, that wouldn't really matter to me.

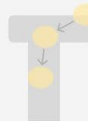
would pull them upwards without using control



That would just kind of pull them I suppose.



When redirecting to the armrests first grabbed these three places
Thinks that a button on the side of the armrest is more intuitive

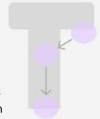
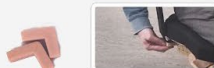


And just drag it upwards I guess. Some some chairs also have like I shouldn't get past the chairs, but it's just this chair. But some chairs also have like button...

This movement feels not so intuitive, feels like her arms are constrained in some way



Suggests a lock unlock position which then gives possibility to then move the armrests up and down



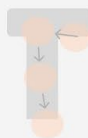
And I figure if I pull it out like this, I would be able to raise it or lower it and then put it back.



would prefer just dragging



dragged it up



I would like to push or pull on them, but it feels kind of like aggressive
also indicated the control underneath armrest



I think I would look for a button underneath and then drag it upwards

demonstrated movement



reaches down first, then up



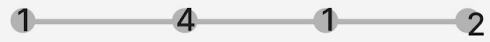
I would press up here to slide them do...

Instinctively reaches to the front



I'm used to just being able to like push a button under it OK and drag it up or push it Down

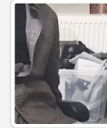
Understanding of the control



1 4 1 2
 didn't use speculated differently speculated similarly immediately understood



was unfamiliar with the type of mechanism Later makes the analogy to a car and that he connects it to seat height for some reason in his muscle memory



Reaches to the back left

All that chose side controls are female



It was unclear, speculated to spin the grips under the seat around



I think I'm thinking about normal like screws and that mechanism like to tighten or loosen the screw.

Would use the tilt lock to move the seat

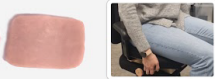


Yeah, sliding it forward or backward, I would actually use that control. And you can. See it. Push it down like this. And put it forward.

Want something that you can grab around and be able to control the whole thing grabbing this control

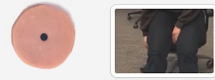


chose 'seat height' control

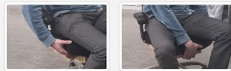


(When asked how to move it)
 The same way I would, press it And I would Like tilt in the way. That I want to go In the office, I think I would just Hold. Like this and then just OK bounce around.

screw forward to move seat forward, back to move backward



Maybe this screw one? I don't know because that feels like a finer adjustment.



Touches very closely to the sides of the chair before arriving to the front

No, because I am thinking of the car seats. Usually there's something here or here which you pull up



reached forward immediately

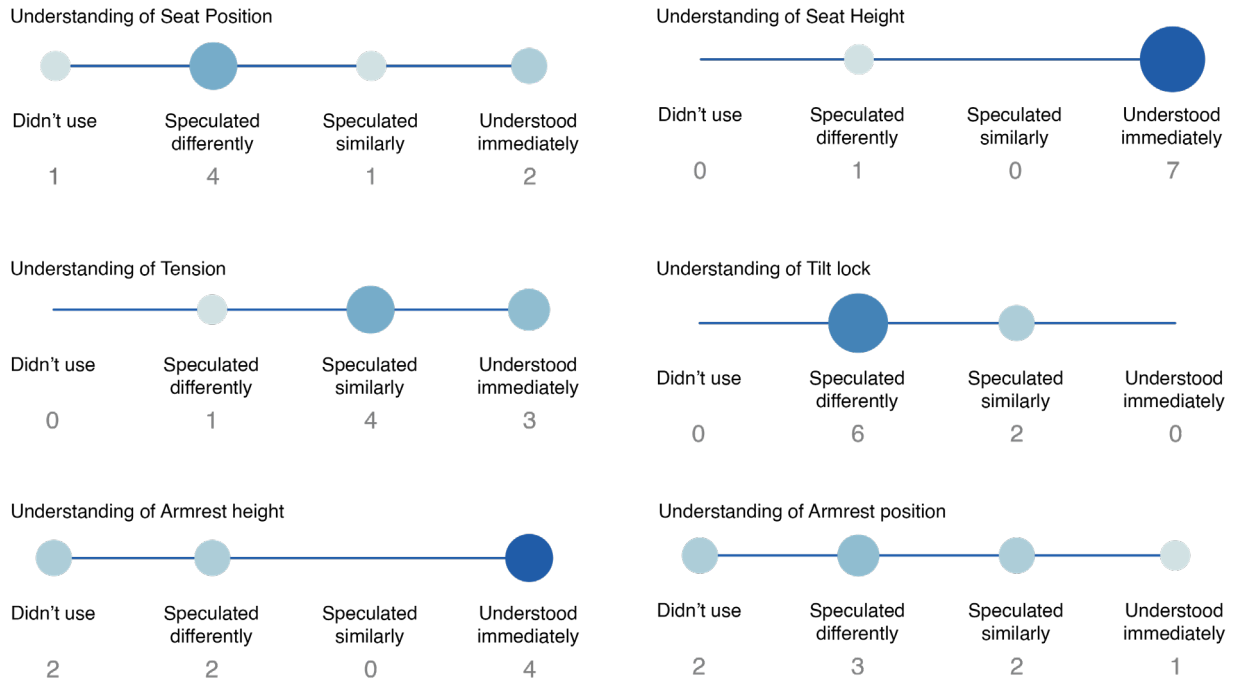
have been working with forklift, always have to change seat position, which is over here

understood from car association chose grip to grab around



one of the first cars that I drove my mum's car had the seat position that you had like a lever on front here

C. User Understanding



IV. Mental Models

A. Benchmarking

Benchmarking	Factor	Seat Height	Seat Position	Tension	Tilt Lock	Armrest Height	Armrest Position
Frequency of occurrence (out of 20)	3,333333333	30	23	23	24	23	18
Adjusted Score (out of 100)		100,0	76,7	76,7	80,0	76,7	60,0

B. Literature

Literature	Seat Height	Seat Position	Tension	Tilt Lock	Armrest Height	Armrest Position
Study 1, Vink et al. (2007)						
<i>Netherlands</i>	88	39	26	22	80	/
<i>Spain</i>	92	20	42	54	49	/
Study 2, Hedge (2016)	46	10	4,1	9,4	31	/
Study 3, Helander et al. (2007)	77	/	1,666666667	65	72,5	/
Study 4,	0,5333333333	0,6	0,6	0,5333333333	0,6	/

Oswalder et al. (2013)							
		60,7	17,4	14,9	30,2	46,6	/
Adjusted Score (out of 100)							

We assume the tilt lock to be equivalent with the backrest angle because the tilt lock control enables locking at any angle

D. User Test

User Test	Factor	Seat Height	Seat Position	Tension	Tilt Lock	Armrest Height	Armrest Position
Understood immediately	100	7	2	3	0	4	1
Speculated Similarly	50	0	1	4	2	0	2
Speculated Differently	25	1	4	1	6	2	3
Didn't Use	0	0	1	0	0	2	2
Understanding in Users		90,6	43,8	65,6	31,3	56,3	34,4

E. Metaphor

Metaphor	Factor 10	Seat Height	Seat Position	Tension	Tilt Lock	Armrest Height	Armrest Position	
Pushing up, using body weight to go down		5						works for up, incongruent going down
Squeeze and drag			8					natural movement, one handed, position could vary
Turning knob				6				strong movement association, but concept of balancing is unfamiliar
Lock and Key					7			old, common association, placement can vary
Press and dragging up						8		grab and drag, natural movement, placement varies
Dragging out							7	natural movement, but placement strongly depends on person
Adjusted Score (out of 100)		50	80	60	70	80	70	

V. Final Control Layout

A. Tilt Lock Concepts

1. Lightswitch, but moving outwards (original control with more visibility & mental model compared to prototype)
 - + Has the same activation for on and off, do not have to remember
 - + constrained by position, only one way to use it
 - + Clear metaphor
 - Not on the same height as the other controls

2. Centre rotation twist
 - + Same level as other controls
 - + lock metaphor
 - Hard to know which movement to do
 = Different movement for on and off

3. Side rotation lever/twist
 - + Same level as other controls
 - off-centred use (might feel strange?)
 = Different movement for on and off

Rating 1-3, 1 worst, 3 best

<i>Requirements</i>	<i>Weight</i>	Concept 1	Concept 2	Concept 3
Follow a mental model	2	3	1	2
Consistent with other controls	1	1	3	3
Controls should be accessible from a sitting position	3	3	2	2
Be discoverable without looking	3	2	3	3
Provide feedback	3	3	1	3
Give use indication	3	2	1	2
<i>Score</i>		37	26	37
Rank		1	3	1

B. Seat Position Concepts

1. Front control squeeze - unchanged
 - + follows convention
 - + direct movement association
 - not found by many in user test
 - have to stand up to use

- (may be worse for women?)
2. Left side squeeze - moves seat in same way as
 - + Visibility/discoverability
 - uneven application of movement
 - does not indicate the next movement? What to do after squeeze
 - Have to stand up to use
 3. Left side slider - moves the backrest back and forth
 - + better visibility/discoverability
 - + don't have to stand up - comparatively easy use
 - + clear direct feedback (users are leaning on backrest when it moves)
 - + single movement (no squeeze required)
 - the control moves by itself/is not static
 - far from the part it controls

Ranking 1-3, 1 - worst, 3 - best

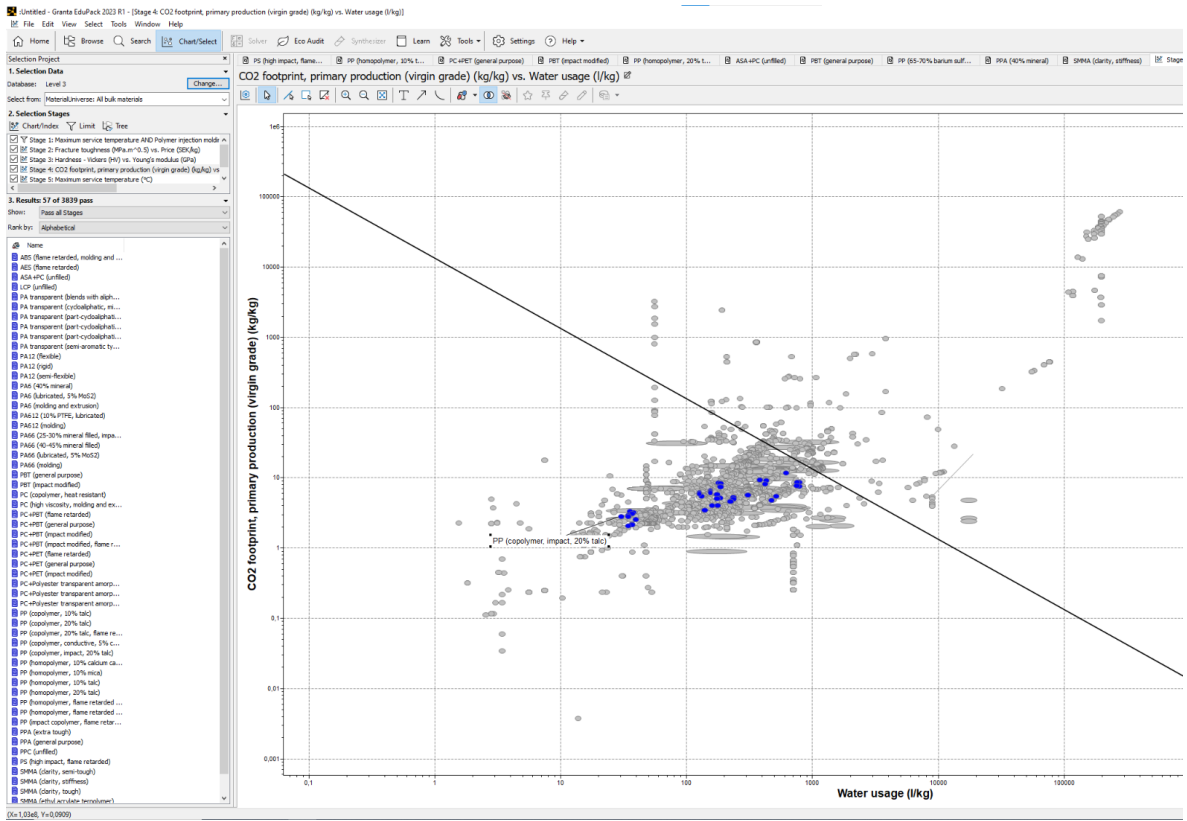
<i>Requirements</i>	<i>Weight</i>	Concept 1	Concept 2	Concept 3
Follow a mental model	2	3	1	2
Consistent placement with other controls	1	2	3	1
Controls should be accessible from a sitting position	3	1	1	3
Be discoverable without looking	3	1	3	3
Provide feedback	3	3	2	2
Give use indication	3	3	1	3
<i>Score</i>		32	26	35
Rank		2	3	1

VI. Material Choice

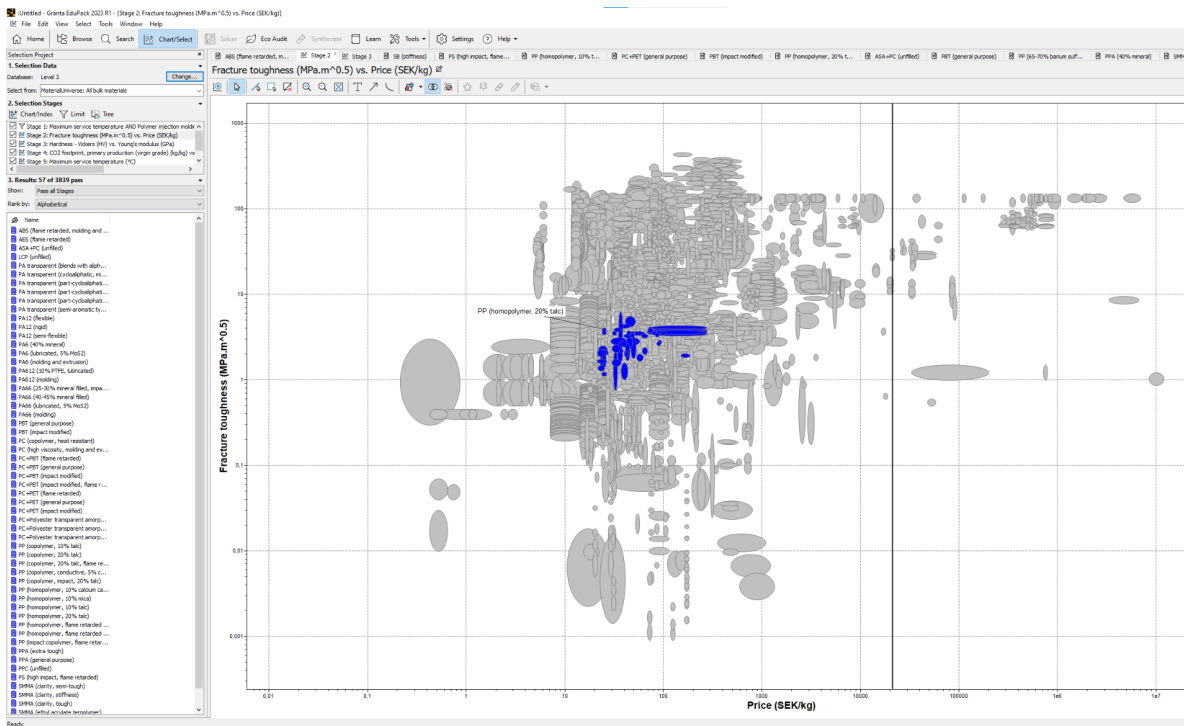
A. Filters used in Granta Edupack

Recycling	Yes
Water (fresh)	Acceptable, Excellent
Water (salt)	Acceptable, Excellent
Flammability	Slow burning, self-extinguishing
Polymer injection moulding	Excellent

B. Chart of the Co2 footprint and water usage



C. Chart of the fracture toughness and price



DEPARTMENT OF INDUSTRIAL AND MATERIALS SCIENCE
CHALMERS UNIVERSITY OF TECHNOLOGY

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