CHALMERS

Redesign of an Ergonomic Computer Mouse

Master Thesis project within the Industrial Design Engineering Program

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Abstract

Computers are used in a constantly growing number of jobs as an aid and tool to facilitate various tasks for workers. Many people keep a static, unnatural posture in front of their computers several hours per day and using the mouse means a repetitive and harmful motion. This may lead to serious musculoskeletal disorders, called repetitive strain injuries, in the shoulder, arm and hand region.

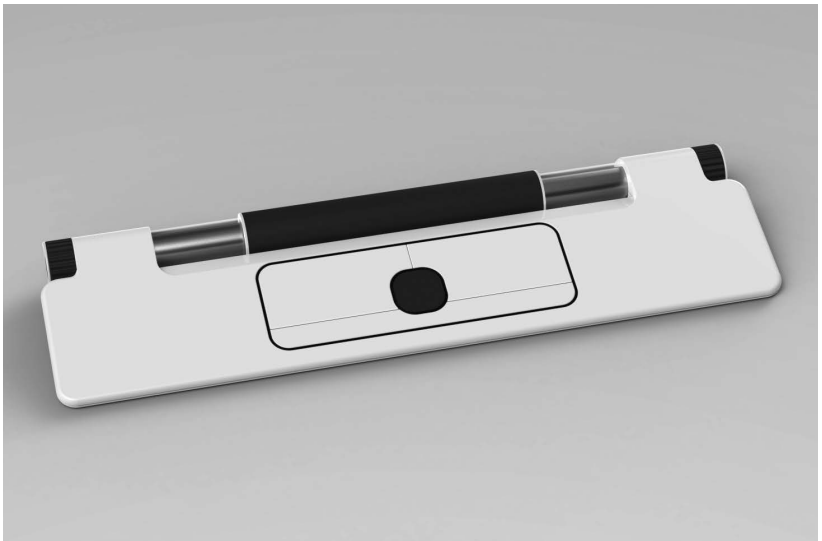
The disorders are difficult to rehabilitate, and sometimes they require surgery, which is both advanced and costly. A way of preventing and also rehabilitate the disorders is to use a *Centered Pointing Device*, which allows the user to keep the hands in a comfortable area in front of the body and close to the keyboard.

Trackbar Emotion is one centered pointing device that coexists with a few other brands and models on a growing market. It has a large roll bar which the user can move to the sides and roll up and down in order to control the cursor on the screen. It also has a number of buttons for clicking actions.

The purpose of this thesis was to redesign the Trackbar Emotion to be more competing, by maintaining its ergonomic benefits and improve the design and functions. The goal was to reach a large target group, both users with little computer experience, and also users with more demanding and advanced work tasks.

In collaboration with the California based company Euro Office a new design was developed through a methodical approach including the research methods usability tests, interviews and focus groups. Thanks to a thorough problem analysis new functional demands were found and the improved design resulted in a thinner device with an open roll bar. There are also two scrollable knobs on the sides of the device which both provide a flexible two hand use, but also, through user customization, allows advanced use with high potential for many different functions.

CURRENT TRACKBAR



FINAL RESULT -
REDESIGNED TRACKBAR

Acknowledgements

Performing this project has taught us a lot, and it has been a great experience to perform the thesis work in the San Francisco region. We would like to thank Mike Sjoblom, CEO and founder of Euro Office, who invited us and made this possible. And let us not forget Magnus Friberg and Arvid Callas, also at Euro Office, who helped us a lot during our three months in California. We hope that the result of this thesis will help the company in future product development projects.

We would also like to thank all the people particpating in our research, specifically the user group at Stanford University, Mr. Mike Fonda, Ann Pudoff and Kristy Schultz and all the other members of Ergonomics Roundtable of Sacramento that helped us.

Finally we would like to thank Lars-Ola Bligård for supporting us as our tutor and supervisor at Chalmers University of Technology in Gothenburg, Sweden.

/Daniel and Jonatan

Contents

1. Introduction

This introductory chapter explains the background and scope of the thesis. The purpose, aim and delimitations are presented.

1.1 BACKGROUND

Computers are used in a constantly growing number of jobs as an aid and tool to facilitate various tasks for workers. Many people keep a static, unnatural posture in front of their computers several hours per day. Together with the repetitive movements of mouse work this may cause physiological problems in the arm, wrist and shoulder regions, often called repetitive strain injuries. Anyone spending much time at the computer may be in the risk zone of developing a disorder, but some people may be more prone. These people are often users that are dependent on computer work and if they develop a disorder they may not be able to perform their job. The problem is magnified when the total number of computer users globally are considered, and how many of them that are dependent on computer work to earn their salary. The phenomenon is rather new, considering the relatively short time computers have been used in most industries.

Repetitive strain injuries are often hard to rehabilitate, symptoms of some disorders may be relieved through surgery, however the best way is to stop doing motions and work that is painful, or preventing the disorders from developing. One way of preventing and rehabilitating the disorders is to use a *Centered Pointing Device*, which enables the user to keep the hands in a comfortable area in front of the body and close to the keyboard. However, it is important to consider that there are a lot of factors contributing to repetitive strain injuries and not just the mouse work.

Trackbar Emotion is one of the centered pointing devices that coexists with a few other brands and models on a growing market. At the moment the Nordic countries, specifically Sweden, is a large pioneer market, but internationally the global market is growing and consequently means great potentials.

1.2 PURPOSE AND AIM

The purpose of this thesis is to redesign the Trackbar Emotion to be more competing in the current and in a future market. It will be achieved by maintaining its ergonomic benefits but simultaneously improve the design with regards to its dimensions, to be optimized for use with both desktops and laptops.

Furthermore the design will be improved to optimize its functions. The result will have an inviting and intuitive design, to be adapted to a large target group. The product will meet current Trackbar users' needs and preferences as well as being attractive to new potential users in a growing market.

The goal is to present a final design with strong competitive looks, feel and functions but also preserving and emphasizing its ergonomic advantages. The result can be used as a foundation to construct models and drawings for manufacturing purposes.

1.2.1 Delimitations

Due to the nature of the purpose and aim of this project, the thesis will not focus on ergonomic studies, but instead use previous ergonomic research and studies in order to preserve, and if possible improve, the ergonomic advantages.

The final result of the thesis will be detailed and manufacturing possibilities will be considered. However, the final design will not be ready for manufacturing and the materials will be discussed but not chosen.

2. Current Situation

The following section explains some main orienting facts about the situation for users as well as some brief information about the company Euro Office, Trackbar Emotion and other competing products.

2.1 DRIVING FACTORS FOR GOOD ERGONOMICS IN A WORK PLACE

In many companies there are several risk factors that may lead to injuries or other work related disorders. If an employee suffers from a disorder he or she has to seek medical advice, perhaps leave work, and stay on sick leave. During that period the company needs somebody to replace that person, whom has to be taught the work tasks. This leads not only to problems and discomfort for the person with disorders, but also extra expenses for the company, keeping a replacement and perhaps paying the victim sick leave compensations.

If the company instead provides the work place with good ergonomic alternatives which reduce the risk of workers suffering from various disorders the total cost could be decreased as well as efficiency and productivity increased. It is important to understand this correlation in order to understand the importance of simple and cheap, but powerful aids in the ergonomic area. (Nussbaum, Julie. 2008). In Sweden, around 70% of all workers use computers in their daily work in order to complete their work tasks, a number that makes it even easier to understand the importance of providing an ergonomic workplace. (Lindegård Andersson. 2009)

2.2 THE CENTERED POINTING DEVICE METHODOLOGY

The main problem with conventional computer mice is the reaching to the side and the motion back and forth from the keyboard. This behavior leads to stress in the muscles which on a long term perspective may result in serious disorders. Therefore, proven by Hedge & Shaw (1996) keeping the hands centered, in front of the body, in a more comfortable zone will give a relaxed posture and consequently less muscle stress and fatigue. This comfort zone is shown in Figure 1.1.

The centered pointing device methodology attempts to minimize the reach by providing the user with a tool where the hands can be kept in the comfort zone. From this philosophy several different pointing devices have emerged in the computer market. Some of the models are presented in section 2.6 COMPETING PRODUCTS.

2.3 TWO MAIN TYPES OF USERS

Users of centered pointing devices can be classified into two main groups; *reactive* and *proactive*. Reactive users are individuals that suffer from musculoskeletal disorders and try various work station improvements in order to rehabilitate. One improvement would consequently be the centered pointing device, whereas others could be adjustable desks and chairs, or supports for arms or feet. The main reason this user group start using the aids is consequently to rehabilitate their disorders.

The other main user group consists of individuals that haven't experienced any problems, but actively and

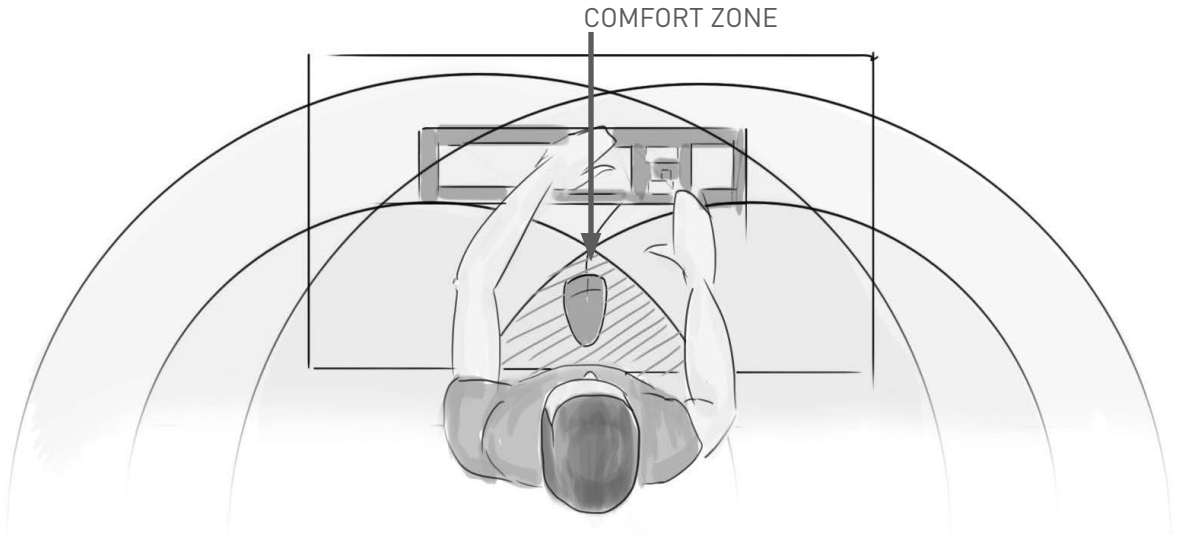


Figure 2.1 The centered pointing device methodology indicating the comfort zone close to the body.

consciously wants to prevent any such disorder from developing. By using ergonomically correct work station tools, like a centered pointing device, the risk of a musculoskeletal disorder is decreased.

The two user groups are consequently differentiated by the reason they start using the product.

In section 6.5 a deeper analysis and explanation of the user groups can be found.

2.4 EURO OFFICE, THE COMPANY

Euro Office is a California, USA, based company that works with ergonomic computer mice. They have been active in the business since the 1990's when they introduced the first Trackbar (fig. 2.2).

The focus has always been to enable the user to maintain the neutral work posture with the hands centered in front of the body. Their centered pointing device, Trackbar Pro, was developed together with medical and ergonomic experts. Since the 1990's, when it was first developed, the Trackbar has gone through some changes and redesigns until the current design (except for some minor changes) was defined in 2006.

Euro Office sells Trackbar Emotion through vendors that distributes to various retailers in its operating regions around the world, as well as through its own web shop. (Eurooffice.com)

2.5 TRACKBAR EMOTION

Developed during the 1990's a simple model of the Trackbar was released, Trackbar Pro, with focus on ergonomic benefits. Since 2006 however, a complete redesign was made and more functions were incorporated as well as a brand new form and design, and it was called the Trackbar Emotion (fig. 2.3). The main elements consist of a large roll and a supportive plastic hull with four buttons and a clickable scroll wheel.

The roll bar controls the cursor movements and provides a large area for the user to use one or more fingers, using either or both hands, which gives many possibilities for individualized use. When the roll bar reaches either end of the device the cursor on the screen resets, meaning that the cursor moves to the end of the screen. The roll bar resets with the help of optic sensors placed on both sides of the device.

The four buttons are configured as left-/right click and back or forward in a web browser.

Trackbar Emotion has a built-in microphone which lets the user enter voice commands to the computer through a third party application. Another optional feature is that the mouse can be turned 180 degrees around where the roll bar is kept closer to the user and may be operated with the thumbs. (Eurooffice.com)

Figure 2.2 The first product, Trackbar Pro, had three buttons and a small roll bar for the cursor control.

Figure 2.3 The current model of Trackbar Emotion.

2.6 COMPETING PRODUCTS

Many of the ergonomic mice on the market are centered pointing devices, among them the two biggest actors are RollerMouse and MouseTrapper, but there are also some other products that make use of other ergonomic principles.

Contour - RollerMouse
RollerMouse is a stationary centered pointing device which exists in different versions. They all share the same basic principles with a wide layout made to fit a keyboard, several buttons and a thin long roll bar for cursor movement. (Contour Design)

BarMouse
BarMouse is similar to both Trackbar Emotion and RollerMouse since it builds on the same principle of a roll bar for cursor control. It has several buttons for both double clicking and also shortcuts for copy and paste. Similar to the RollerMouse, it has the same width as a stationary keyboard. The BarMouse doesn't require any drivers to be used in a standard computer, instead it has switches on the backside to reprogram the buttons. (Ergoption)

MouseTrapper
The MouseTrapper has a low profile thanks to its flat pad, which is used to control the cursor movement by sliding it with the finger. The pad itself follows the fingers' motions, which reduces any friction on the fingertips. The design is wide, to fit a regular keyboard. (http://www.mousetrapper.co.uk/home.html)

Nomus Navigator
The Nomus Navigator has a similar design to the BarMouse and RollerMouse, with a long thin roll bar for cursor control and several buttons for shortcuts like copy/paste and double-clicking functions. It is wide to fit a regular keyboard.
(http://www.nomusnavigator.com/)

Kondator - Ergoslider
Ergoslider has the same principle with a long and thin roll bar, only it has a free area to be moved around and can also easily be removed for cleaning. It has five buttons and the same width as a regular keyboard. (http://www.kondator.se/)

Evoluent

Evoluent is not a centered pointing device, but intends to reduce the stress in the arm and hand by keeping the wrist and hand in a vertical position, which is supposed to be more natural and neutral. It has a large grip and is designed for use with one hand. There are both left- and right handed versions.

Evoluent is not the only vertical computer mouse on the market, there are several others that make use of the same principle. However, it is not necessary to mention all of them. (http://www.evoluent.com/)

Wacom Pen Tablet

The Pen tablet is not aimed to be a stress relieving product, but only marketed as an alternative input device where a digital tablet is used together with a pen, and senses the motion and pressure from the tip of the pen. It is used for a high precision input where the work requires a high similarity to a regular pen, like illustrations, drawings etc. (http://www.wacom.com/)

Touch pad

A touch pad is usually integrated into a laptop chassis, and uses a digital touch sensitive surface which detects the motion of the finger tips. It can be used together with separate buttons, or have the click function integrated into the touch area. The touch pad is located near the centre of the computer close to the space key.

3. Ergonomics

This chapter is a theoretical description of the most common work related disorders followed by guidelines for ergonomic work place design. Finally cognitive ergonomics is explained.

When designing a centered pointing device it is important to have an understanding of the different disorders related to computer work as well as how and why they develop. Further, elementary knowledge about the anatomy of the arm and wrist is important to understand the theory.

3.1 ANATOMY

The arm is a complex limb, consisting of many muscles, bones and tendons. Figure 3.1 illustrates the different muscles of the arm and shoulder.

Figure 3.2. describes the different positions and movements of the forearm, wrist and hand. Flexion, extension, radial and ulnar deviation occurs at the wrist joint while pronation and supination occur in the forearm, in the connection between the ulna and the radius bones (Pheasant, 1996).

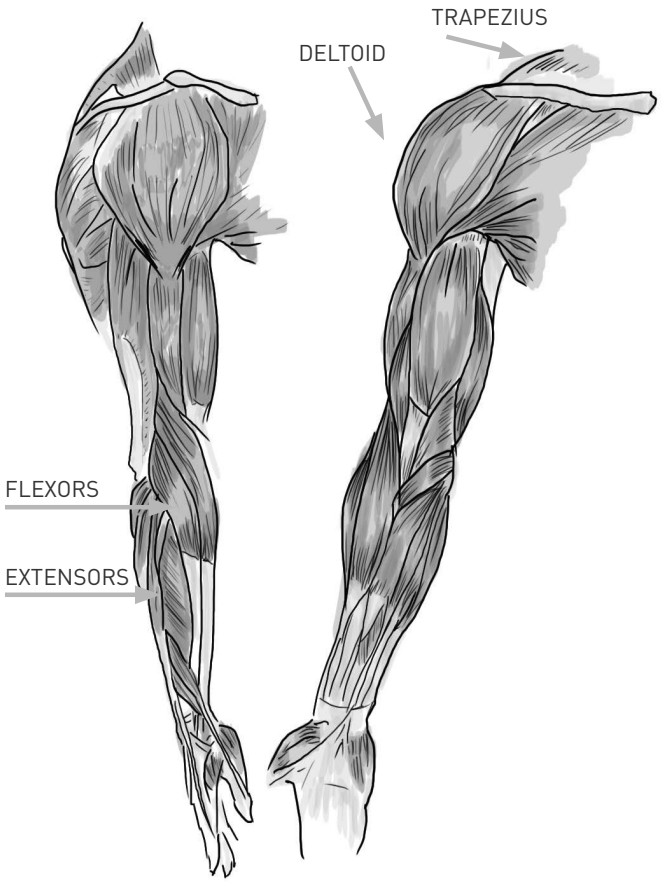


Figure 3.1 Relevant muscles indicated in the shoulder and arm region.

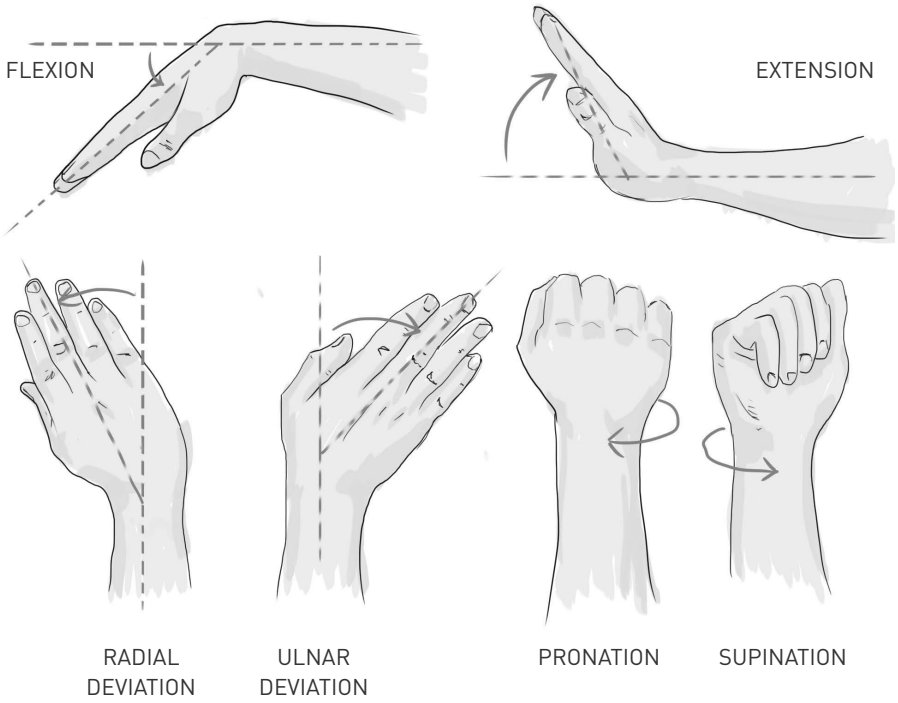


Figure 3.2 The different ways the wrist can be moved.

3.2 WORK-RELATED MUSCULOSKELETAL DISORDERS (WMSD)

Repetitive tasks require a combination of both static and rhythmic muscle activity. In order to perform tasks that require fine motor skills, stabilization needs to be provided by muscles farther up the kinetic chain, such as muscles in the lower and upper arm as well as muscles in the shoulder and neck region. Extensive work with repetitive tasks may lead to medical conditions, either in the muscles supporting the stabilization or in the muscles and joints performing the task, or in both (Bridger, 2003).

It's not clear to what extent the musculoskeletal disorders are caused by work, since they can arise as a result of many other things, including non-work-related activities. There are two sides in the debate about the work-relatedness of WMSD's; one that believes pain experienced at work must be caused by the actual work and that the pain itself is evidence of a medical condition. The other side believes that there is a lack of evidence of the work-relatedness of the disorders, and that light pain and ache experienced at work are reversible (Bridger, 2003).

A commonly used expression regarding WMSD's is Repetitive Strain Injury - RSI. According to van Tulder et. al (2007) RSI is not a diagnosis but rather an umbrella term for multiple disorders, such as Carpal Tunnel Syndrome, Lateral Epicondylitis (or tennis elbow), tendonitis in the wrist and hand, and other upper limb disorders. There is an association between RSI and physical risk factors such as repetitive movements (hence the name), poor posture, and inadequate strength. Associations of work-related and psychosocial factors are not as clear. However, there is some evidence that high workload, stress, high demands, low job security and little support from colleagues may be contributing factors (van Tulder et. al, 2007).
WISHA Services Division, Washington State Department of Labor and Industries (2002) presents some common risk factors for WMSD's which are:

- **Repetition** – identical or similar motions performed repeatedly without any time for rest and recovery. E.g. typing on a keyboard, moving and clicking the mouse and looking back and forth between the monitor and source documents.

- **Static loading** – the muscles must hold the body in the same position for a long period of time, which reduces circulation and causes muscle tension. E.g. holding the hands above the keyboard or mouse, holding down keys or sitting still for long periods.

- **Awkward postures** – joints bent and held in positions where they are more likely to become injured. E.g. typing with bent wrists, turning the head to the side to view the monitor or reaching for the mouse over the keyboard.

- **Mechanical contact stress** – hard or sharp surfaces pressing into soft tissues (tendons, nerves and blood vessels). E.g. resting wrists on the desk edge while working, leaning elbows on hard surfaces, typing with palms resting on the hard lip of a keyboard tray.

Some of the main work-related disorders often associated with computer work are presented below.

3.2.1 Carpal Tunnel Syndrome - CTS

The carpal tunnel is a narrow opening in the wrist which is traversed by the nerves and blood vessels of the hand. The fingers are flexed by muscles in the forearm with the help of long tendons also passing through the carpal tunnel. An illustration of the wrist is shown in Figure 3.3.

Repetitive flexion and extension of the wrist and fingers under stress may cause inflammation in the tendon sheaths. To facilitate the motion of the tendons, a lubrication fluid is secreted, and the buildup of excessive fluid causes an increased pressure in the carpal tunnel. The pressure may affect the median nerve or the blood supply to the nerve, resulting in CTS. Typical symptoms of CTS is a sensation of tingling and numbness in the palm and fingers, pain and loss of dexterity (Niebel & Freivalds, 2004)(Bridger, 2003).

Carpal Tunnel Syndrome is associated with high force and repetitive work, as well as with vibration of

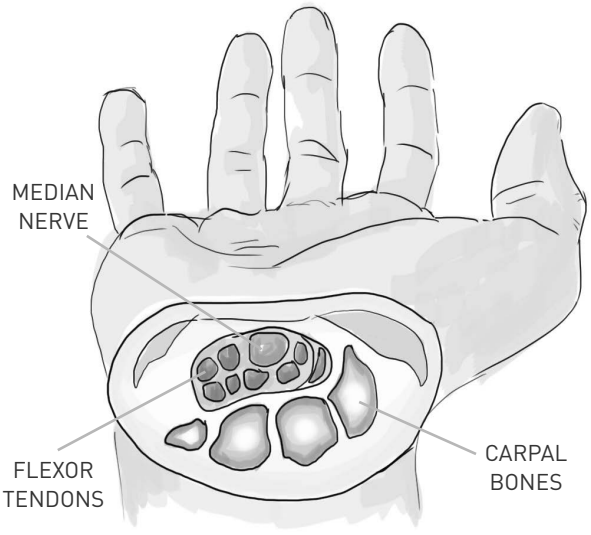


Figure 3.3 Section of the wrist and the elements involved in Carpal Tunnel Syndrome

the hand and wrist, but extreme postures on their own are not (Bridger, 2003). A study made by Andersen et. al (2003) identified that there was an association between tingling and numbness in the right hand and time spent using a mouse device. However the study emphasizes that computer use does not pose a severe occupational hazard for developing symptoms of CTS. Niebel & Freivalds (2004) stress that the wrist position largely affects the strength of the hand, and awkward unnatural positions and angles may lead to soreness or loss of grip. If these positions are sustained for a long period they can result in CTS.

Carpal Tunnel Syndrome may be rehabilitated through the use of immobilizing hand braces or open carpal tunnel surgery release (van Tulder, 2007). Exposure to vibration, highly repetitive work and extreme postures in combination should be minimized to help lower the prevalence of CTS in the workplace (Bridger, 2003).

3.2.2 Tennis Elbow (Epicondylitis)

Sudden and often repeated use of the wrist extensor muscles can lead to a condition called Tennis Elbow (Flatt, 2008)). The act of grasping and holding objects requires the wrist to be stabilized by the muscles of the forearm. When the finger flexors contract to grip an object the wrist extensors also need to contract to stabilize the wrist. These forces are transmitted across the elbow and the tendons in the joint are being tensed and may become swollen, fig. 3.4 (Bridger, 2003).

According to Bridger (2003) there is insufficient evidence to support an association between repetitive work, posture and tennis elbow, but there is strong evidence for an association between combined stressors and tennis elbow. Any activity that requires a strong grip for a long period of time will place a load on the elbow joint.

The best way to rehabilitate tennis elbow is to permanently avoid the movements that caused the symptoms in the first place. Another way to relieve the pain is through physical therapy, such as massage or ultrasound. Tennis elbow can also be treated with surgery, it is however not the primary treatment (Flatt, 2008).

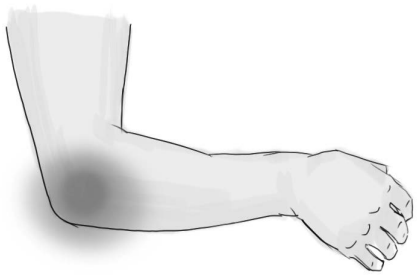


Figure 3.4 Tennis Elbow leads to pain in the red highlighted area.

3.2.3 Tendonitis

Tendonitis is an inflammation of the tendons caused by impaired blood supply. Highly repetitive movements increase the blood supply to the muscles, and in turn decrease the blood supply to associated tendons and ligaments. This results in an increase of cell death in the tendons and the immune system causes an inflammatory response (Bridger, 2003).

When tendonitis occurs in the wrists and hands it is known to be work-related, and impaired blood supply to the tendons is considered the cause of much occupational shoulder pain. It has been shown that tendonitis is associated with highly repetitive activities, and there is evidence that force, posture and repetition are all associated with the disorder, even stronger when the factors are combined (Bridger, 2003).

3.2.4 Shoulder disorders

Most work involving hand tools expose the body to repetitive and static loads that involve the shoulder, if only indirectly. Using hands and arms without support, forces the shoulder to hold the weight, and muscle activity is required to hold the shoulder joint in place. These repetitive actions and static loads may cause fatigue or damage to the shoulder and surrounding tissues (Bridger, 2003).

The use of conventional mice and keyboards require the hand to rest flat. The pronation in the forearm to rest the hand horizontally is however anatomically unnatural, and to ease the pronation the elbow is lifted causing tension in the shoulder (Kroemer et. al, 2001).

Working with the hands near the waist level and close to the body is a method to reduce shoulder stress. If that's not possible, an external support for the weight of the arms is necessary. Work objects should be placed within the zone of convenient reach and breaks should be taken regularly (Bridger, 2003).

3.2.5 Neck disorders

The rear neck muscles keep the head up straight and help maintaining a natural and balanced posture. Their roles become clear when a sitting person falls to sleep and the chin falls towards the chest because the muscles relaxe. Therefore any additional stress in the neck muscles may lead to overexertion, causing fatigue or pain. The trapezius muscle helps the extension, lateral flexion and rotation of the head, and since it plays an important role in many work activities and is involved in elevating the shoulders, overexertion may contribute to neck pain (Bridger, 2003).

There is a relationship between neck pain and neck flexion, arm force, arm posture, duration of sitting, twisting or bending of the trunk, hand-arm vibration and workplace design. However, it is only for static posture and twisting and bending of the trunk that there is firm evidence of the relationship (Bridger, 2003).

3.2.6 Trigger finger

Intensive pressing and holding buttons may lead to a condition called *Trigger Finger*. It is caused by the thickening of the fibro-osseous canal through which the finger flexors pass and leads to stiffness and snapping of fingers during flexion. It has been found that there is a higher prevalence in occupations where static grasping of triggers is involved (Bridger 2003). There is also a risk of developing trigger finger through repetitive finger action (Niebel & Freivalds, 2004).

3.3 GUIDELINES FOR THE DESIGN OF A WORKPLACE

Injuries and disorders may be avoided by setting up the workplace in an ergonomic correct way. Below is a list of guidelines to help avoid musculoskeletal disorders while using a mouse and keyboard.

Breaks are helpful – Taking a break now and then, to let the muscles relax for a couple of minutes, is good.

Keep the hand away from the mouse - Removing the hand from the mouse when it's not being used is very helpful, a mouse that vibrates when it's not been moved for some time can be used as a reminder to remove the hand.

Maintain a neutral wrist position – The wrist should be held in a neutral position with some space underneath. The forearm should float along with the mouse which allows the larger muscles to contribute to the task (Nussbaum, 2008). The workplace should be designed so that it facilitates the hand and joints to be held in a natural posture (Niebel & Freivalds, 2004). If a conventional mouse is used, it is advisable to use a keyboard without a numerical pad so that the mouse can be placed closer to the center line. It has also been proven that a mouse that keeps the wrist in a neutral position can reduce musculoskeletal disorders (Pheasant, 1996).

Working posture – No fixed position should be held, variations in working posture is desirable. Twisted and asymmetrical postures should be avoided and no upper limbs should be kept in a raised position. Static loading on arm, shoulder and neck regions should be minimized and therefore the arm and hand should be supported to relieve the upper arm, shoulder and back muscles (Kroemer et. al 2001. Pheasant, 1996). Keeping the arm and elbow away from the body can result in fatigue, the best position for the hand is in front of the body at elbow height and the elbow should be kept at 90 degrees (Kroemer et. al, 2001. Niebel & Freivalds, 2004). A neutral posture can be seen in Figure 3.5.

Avoid prolonged static muscle loading - Static load may lead to fatigue, reduced work capacity and soreness. Furthermore, constantly holding a button or switch also triggers fatigue and reduced flexibility (Niebel & Freivalds, 2004).

Avoid repetitive motions – The joints should not be used in a repetitive way for long periods of time, particularly important for the forearm, hand and wrist (Pheasant, 1996). Repetitive finger action should also be avoided to minimize the risk of trigger finger (Niebel & Freivalds, 2004).

Design for both hands – Handheld tools should be designed to be used with either hand, because 10% of the population are left-handed but also to allow users to temporarily reduce the load of the primary hand if they wish (Niebel & Freivalds, 2004).

Use keyboard shortcuts - A variety of keystrokes can be used to relieve some mouse work (Nussbaum, 2008).

Keyboard work – When typing on a keyboard wrists

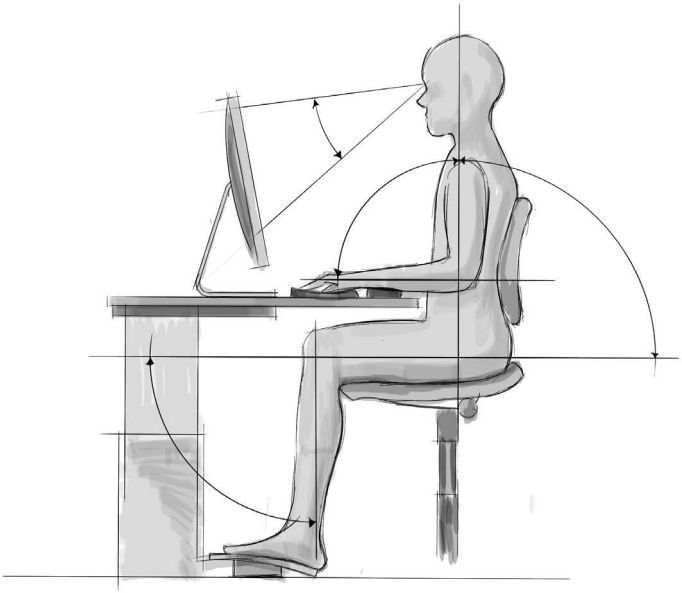


Figure 3.5 The figure shows a person working by a computer in a relaxed posture with neutral wrist angles.

should stay in a neutral position. The keyboard should be as thin as possible to minimize the angle of attack. ISO standards suggest at least 100 mm hand support in front of the input device and the rest should be free from sharp edges that cuts into the wrist. Standards also recommend a maximum pressing force of 1.5 N, a key displacement should be between 2 and 4 mm and provide tactile feedback (Pheasant, 1996).

3.4 COGNITIVE ERGONOMICS

Cognitive ergonomics has to do with how users perceive information and make decisions. Presented below are two fields of cognitive ergonomics; *usability* and the *gestalt principles* of form and perception.

3.4.1 Usability

The ISO-definition of usability is "…the extent to which a product can be used with effectiveness, efficiency, and satisfaction by specific users to achieve specific goals in a specific environment". Simply put: how easy, effective and satisfying the product and its functions are to the user. It is about optimizing the functionality, ease of use and understanding of a product to make it easier for the user (Jordan 2002).

To optimize a product, five main aspects have to be taken into account, either combined or one at the time depending on the type of product. The five aspects that should be regarded are *Guessability, Learnability, Experienced User Performance, System Potential* and *Re-usability*.

- **Guessability**: A measure of how easy it is for the first-time user to guess how various functions work or what different icons and buttons mean.
- **Learnability**: A measure of how fast and good a user can learn different meanings and functions in the system after using them only a few times.
- **Experienced User Performance**: A measure of how well an experienced user can make use of the system. Different assisting functions, such as keyboard short-cuts, become important.
- **System Potential**: The theoretic potential of the system, i.e. how well the system can perform a task in theory.
- **Re-usability**: A measure of how easy it is for a user to perform a specific task again after doing it a long time ago. Consequently, how easy it is for the user to remember how different tasks are carried out.

Jordan (2002) also presents ten principles for usable design:

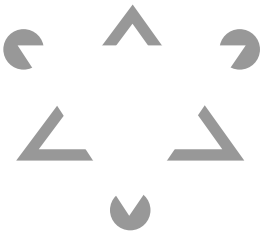
- *Consistency*: Similar tasks should be performed in similar ways.
- *Compatibility*: The procedure of performing tasks should be compatible with the user expectations stemming from earlier knowledge about other products and contexts.
- *Consideration for user resources*: The procedure of performing tasks should take the user resources into account.
- *Feedback*: When a task is performed the user should be alerted, through meaningful indications, about the result.
- *Error prevention and recovery*: The risk of user errors should be minimized and recovering from a potential error ought to be simple.
- *User control*: The users control of the functions should be maximized.
- *Visual clarity:* Information should be displayed so that the user can interpret it fast and easy.
- *Prioritization*: The most important functions and information should be easy accessible to the user.
- *Appropriate transfer of technology*: Technology developed in other contexts ought to be adapted and used to improve the usability of the product.
- *Explicitness*: Explicit cues should be given about the product's functions and use.

3.4.2 Gestalt principles of form perception

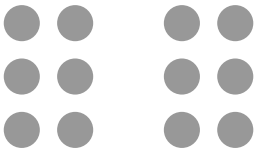
In interaction design there are some important aspects that determine how the product or image is understood by the viewer. These are commonly called gestalt laws and they are classifications of different characteristics of shapes that influence how the whole image is perceived. It is the organization and combination of the elements that is taken in to consideration. As a designer it is important to understand these laws and how they may influence the perception (Johannesson et. al, 2004)

The laws mentioned at Interaction-design.org (2009) are the law of proximity, the law of similarity, the law of prägnanz, the law of symmetry and the law of closure.

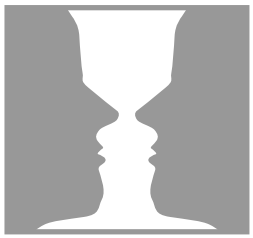
The law of closure: The human interprets lines and surfaces as shapes, even if they are separate objects. The mind perceptually closes or completes objects that are in fact not complete. The law of closure can counteract the law of proximity since it appears to be stronger.



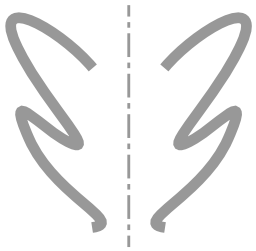
The law of proximity: Objects close to each other are perceived as a group that belong together, and they are assumed to have something in common.



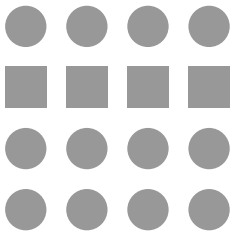
The law of prägnanz (figure-ground): This law is about how the human perceives a visual field. Some objects will appear to be prominent (the figure) while some objects remain in the background. Consequently, some objects may be the figure standing out for one moment, but in the next or for another viewer appear to be the background.



The law of symmetry: The viewer usually seems to interpret objects in symmetric patterns. The objects are perceived as symmetrical shapes forming around the center and even though they differ, a certain grouping is perceived thanks to this phenomenon.



The law of similarity: Objects with similar shapes and colors are perceived to belong together and form a group. They are bound together by their similarity, even in a chaotic arrangement they can be grouped due to the similarity.



The law of experience: A shape is easier to perceive if the viewer recognizes it and if it fits with what is known before (Johannesson et. al, 2004). For example the image to the right could be interpreted as the letter B or the number 13, depending on the viewers experience.

4. Methods

The following section describes the theoretical implementation of the methods, in alphabetical order, used in the report in order to complete the product development process.

4.1 CAD - COMPUTER-AIDED DESIGN

CAD (Computer-Aided Design) software is used in many industries to simulate real life objects or products. It is a fast and effective way of testing processes and operations.

Objects are built in a three-dimensional environment using mathematically computed vectors, which the designer has the control to adjust and reconfigure. The objects are constructed with surfaces or solids and can be used to visualize a product or to test a process, Figure 4.1.

The objects can be rendered into photo realistic images to represent a real product to present and communicate ideas and designs to stakeholders or customers.

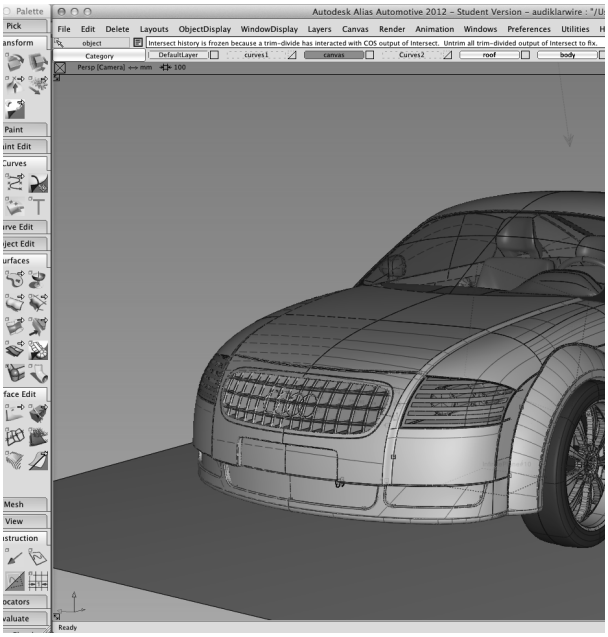


Figure 4.1 The CAD-software consists of several tools for building mathematically calculated surfaces in a 3D-environment.

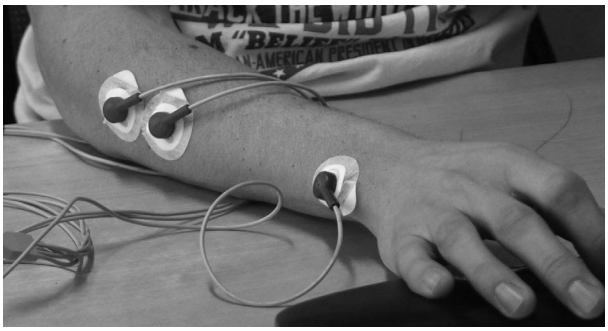


Figure 4.2 EMG-measurements of the lower arm. Electrodes are attached to the muscles and signals sent to a computer.

4.2 EMG-MEASURES

The activity in a muscle can be detected using electrodes that are placed on the skin or inside the muscle using a method called *electromyography*, or *EMG* for short. When electrodes are placed on the skin, the measurement will show the sum of the activity in several muscle motor units, Figure 4.2. An EMG analysis will show the amount of muscular activity and can therefore be a tool to compare different tools or postures and understanding where the highest stress occurs. (Hägg et. al. 2009).
When performing EMG measurements it is important to know that the results are highly dependent of an individual test and the individual. Factors such as muscular force, fatigue and stamina will affect how the muscles of an individual performs. This means that it is virtually impossible to compare EMG measurement either between individuals or measurements on the same individual from different occasions.

4.3 FOCUS GROUP

A *focus group* can be used during an informal meeting, lasting around an hour, where six to ten individuals are asked to discuss a predetermined topic. The interviewers are there to observe and take notes and also facilitate the discussions and occasionally lead the participants in the right direction. Sometimes it can be useful to take advantage of objects or images as a trigger for discussion. The method provides the interviewers with qualitative data, and can cover products, experiences, methods, places and many other topics. (Bohgard, et. al., 2008).

4.4 IDEATION (BRAINSTORMING & IDEA CARDS)

The *ideation* phase of a product development process can be facilitated through the use of *brainstorming*. It is a session where two or more participants freely discuss a problem to which they want to find solutions. The goal is to find new innovative ideas to the problem. Any solutions are welcome at this stage, no ideas are bad and no participant is allowed to criticize any ideas or other participants.

It is important to document all ideas so they are not forgotten during the session, and sometimes a leader is useful in order to keep the participants on the right track. (Quality Tools; Brainstorming. 2007)

The brainstorming in this project was aided with sketching to find visual and functional ideas.

4.5 IMAGE BOARD

An *image board* is a collage or a composition of several images on a large board that is displayed to the work group and designers. The image board is used as inspiration for new ideas, or setting the work group in a specific mood for the situation. It can also be used to communicate various attributes internally, to ensure that everyone is working towards the same goal. Image boards are useful in contexts where facts and figures are not applicable to describe a certain goal. (McDonagh, Bruseberg, & Haslam, 2002)

Two different kinds of image boards have been used in this report. The *mood board* consists of slightly abstract images that together communicate a feeling with their shape, color and character. The *inspiration board* contains pictures of competing products, similar products or other objects that represent values and attributes that the result of the ideation should give.

4.6 INFORMAL USABILITY TESTS

A quantitative way of quickly finding first time use experience usability problems with a consumer product. By asking, with no preference of demographics or other experiences, a group of around ten individuals to test a product for the first time, a number of issues can be found. The individuals are asked to perform one simple task and then try the product freely during five to ten minutes. During the test the user is observed and any interesting behavior, errors or other reactions are noted. After the test the user is asked to leave any comments about the experience. This method was developed during the process by the authors.

4.7 KJ-ANALYSIS

The *KJ-analysis* is an effective way of managing and sorting a big amount of data. It is useful when lots of information has been gathered concerning a problem and the information is difficult to oversee and comprehend.

Each fragment of the data is noted on a card, or often post-it note, and then each card, one at a time, can be processed and categorized. The KJ-analysis will consequently result in a number of groups, wherein pieces of information are gathered, which can be further analyzed or processed. The groups are given a name according to their category for easier handling. Through this method a large or incomprehensible problem can be divided into smaller clusters that are more easily dealt with (Fig. 4.3). (Karlsson. 2007)

4.8 LIST OF FUNCTIONS

The functions that the final product should have are listed and described in a concise manner. Each function is described with a verb and a noun, and then weighed on a scale from 1 to 5, in accordance to their importance. Each function can be further described with a short comment if needed.

The functions should not be focused around solutions, but rather be as abstracted as possible. This enables the designer to be open for many different ideas for solutions at an early stage. (Wikström, 2004)

In this project the list of functions was adapted to include notes for each function about what user group and what problem area they belong to.

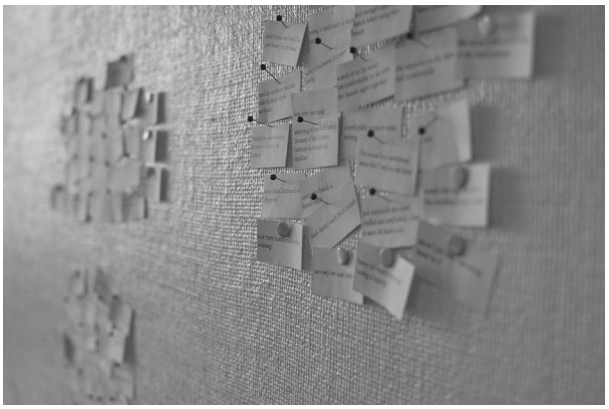


Figure 4.3 A KJ-analysis gatheres several notes in different categories, which are visualized on for example a wall.

4.9 LITERATURE STUDIES

In order to find information within a certain topic literature of different kinds can be consulted. The media may be printed or digital and the information can be found by searching through online databases to find articles, books, journals or other published material. Literature studies is a good way of taking part of previous research and known facts. (Bohgard, et. al., 2008).

4.10 LONG-TERM USE TEST

A *long-term use test* consists of a number of individuals that are asked to try and use a product for the first time during a period of around two weeks. The user should try to use the product as much as possible in order to be able to gain as much experience as possible.

At the initiation of the test the researchers present the test and the product to the participants and may hold a brief discussion of the users' previous experiences or backgrounds. This enables the researchers to draw conclusions from the use experience after the test.

After the test the participants are gathered in a focus group and asked to discuss any pros or cons regarding the product.

This method was developed during the process by the authors.

4.11 MARKET RESEARCH

To learn more about the current market, competitors and existing technology, *market research* can be made to obtain that information. It is conducted by searching online communities, retailers and consulting stakeholders in the specific industry. The market research results in a knowledge bank that can be consulted internally in the product development process. This method was developed during the process by the authors.

4.12 MORPHOLOGICAL MATRIX

A *Morphological Matrix* is a way of finding combinations of partial solutions and developing more complex concepts. The matrix consists of rows with areas of solutions, where each row has its own category. Listed in each row are the different partial solutions that have been found during an idea generation phase.

The matrix is used to find variations of the concepts by combining different partial solutions through different routes along the matrix and the problem areas. It is partially good for ensuring that no area is missed but also effective in finding new innovative combinations. (Johannesson et. al. 2004)

4.13 PERSONAS

Personas are fictive characters that are created based on the research and information gathered for the specific topic or problem. Using personas is an effective way of bringing the target group or user to life, to facilitate work and discussions internally at a company or in a work group. Personas can also be used as inspiration in the idea generation phase. Personas are easier to identify with than pure facts and figures.

From the research and background information a fictive person is created, preferably as realistic as possible, representing the desired user. Name, photo, background story, habits or experiences are useful elements in the description of the persona. (Design and Emotion: Personas)

4.14 PHYSICAL MODELS - MOCK-UPS

Using cardboard, plastic foams, wood or other easily processed materials *mock-up* models can be produced during a product development process. It is a useful method for finding correct life-size dimensions, since the models become three-dimensional compared to sketches. Life-size models are easy to comprehend, since the ideas can be touched and felt in real life and volume, angles, shadows etcetera are actually experienced. This gives the designer a strong sense of the intended design, which he later can revise and improve.

Models can be used both as an internal verification of design, but also as a presentation for external stakeholders or during use tests and evaluations.

4.15 QUESTIONNAIRE

A *questionnaire* is a set of questions that are sent to respondents who will reply individually and then send the replies back to the researchers. The questionnaire can consist of either open or closed questions, or a combination of both. An open question gives the respondent the possibility to reply freely with their own words. However, this could mean that the questionnaire takes a long time to complete and that the respondent will not finish or give detailed answers on all questions. Closed questions mean that the respondent is given predefined multiple choice answers, which might make the answers too shallow and general (Karlsson. 2007).

4.16 SEMI-STRUCTURED INTERVIEW

A personal interview consists of an interviewer that asks questions to the interviewee. In the *semi-structured interview* the interviewer knows what will be discussed and what kind of questions that will be asked. There is however no predetermined set of questions that have to be followed, but the interviewer may follow the discussion and adjust the questions to the situation. The interviewer may consequently ask follow-up questions in order to fully cover the topic and learn as much as possible. (Lindlof et. al. 2003)

5. Work Process

This section explains the process that the product development has followed. The steps will be explained briefly in terms of why they were performed and how they lead to the next step.

5.1 PROCESS FLOW CHART

The work process was divided into three parts; background, problem definition and design proposal. The background involved theoretical studies and market studies which resulted in an understanding of the current situation. The problem definition involved all the studies performed by the authors and resulted in a definition of the needs and functions. Finally, the design proposal phase involved an iterative conceptual phase that resulted in a final design. The process is illustrated as a flow chart in figure 5.1 below.

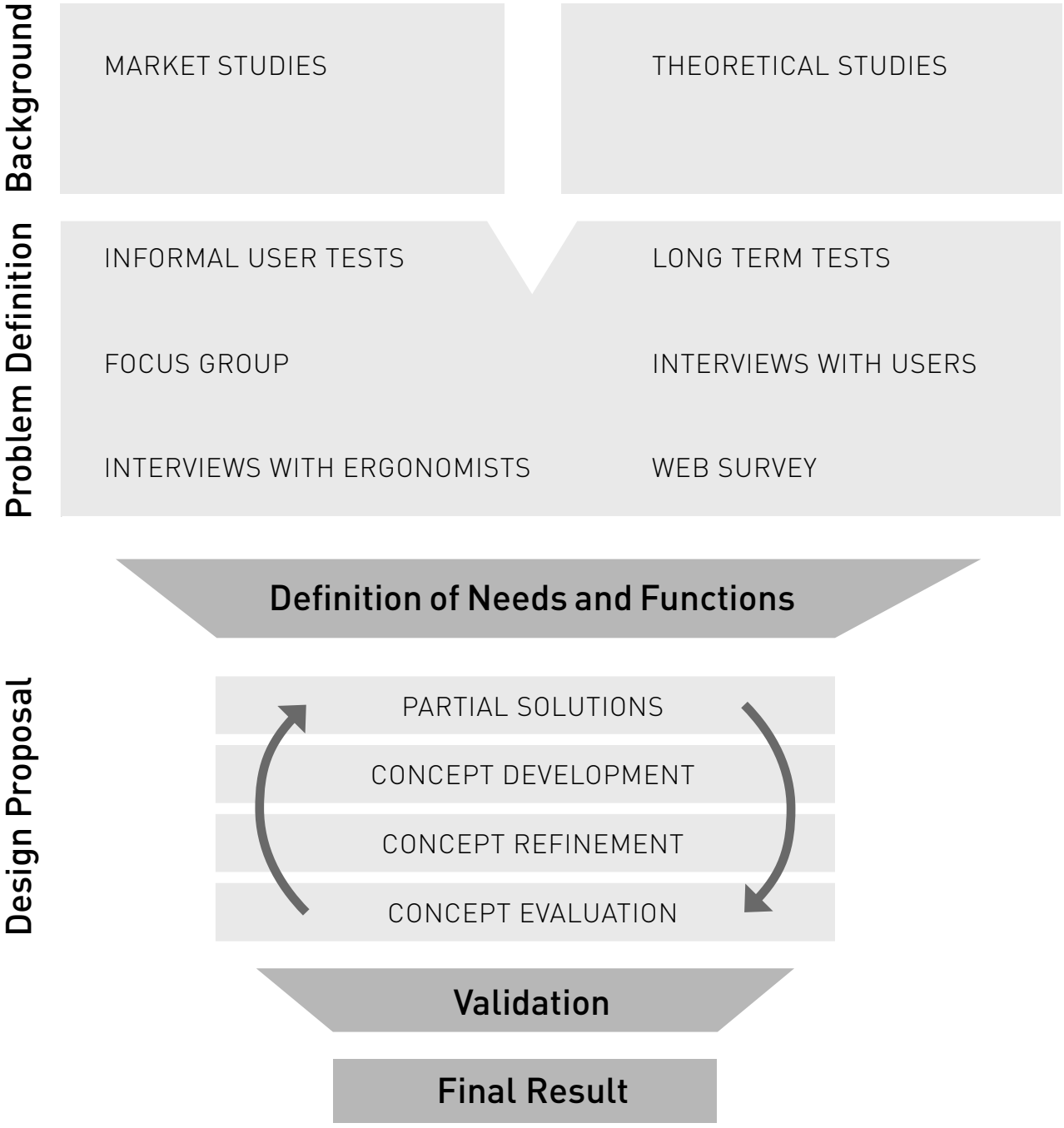


Figure 5.1 The design process is illustrated as a flow chart.

5.2 BACKGROUND AND THEORY

The first steps were to find background information about the current market situation, competing products, and also about the ergonomic research and facts.

5.2.1 Ergonomics

In order to understand the reason for using a centered pointing device and the different ergonomic aspects that are associated with computer work various literature was consulted. Basic anatomic information regarding the arm-/shoulder region was comprehended through literature, as well as the most common disorders that are related to computer work. This information was useful to know the features that are necessary for a centered pointing device, as well as the boundaries that exist for a design.

5.2.2 Market research

The market was analyzed to understand the different products that exist today. This research provides not only information about existing solutions and technologies but also inspiration and ideas regarding which solutions are feasible, innovative, existing and so on.

5.3 PROBLEM DEFINITION

To fully understand the problem that needs to be solved several different approaches were used; informal tests, interviews with experts, focus groups and questionnaires.

5.3.1 Informal user tests

First several **informal user tests** were performed in order to understand any first impressions of the Trackbar, and to quickly identify what different usability or cognitive issues there may be. Any positive or negative feedback from the users would help in understanding which pros and cons the current model has, in order to know what could be kept and what should be changed in the redesigned version.

The tests were performed with men and women between 20 and 30 years old with average computer experience.

5.3.2 EMG test

Due to an observation in the informal users test an EMG test was performed. The intention was to find any differences in muscle stress from using the Trackbar with one or two hands.

Four different muscles where tested in the **EMG test**; Trapezius and Deltoid in the shoulder as well as one flexor and one extensor in the forearm.

First two different postures were tested, one controlling the Trackbar with one hand and the other using it with both hands simultaneously.

One test was also performed where three different input devices were compared; a conventional mouse, Trackbar Emotion and MouseTrapper. They where chosen because they all use different input methods.

Both tests were performed at the same occasion.

5.3.3 Focus group

In order to learn more about what needs and opinions users with actual problems have, a **focus group** was assembled. The participants were both men and women who suffered from different kinds of repetitive strain injuries, they were all architects and their computer skill can be considered to be above average.

The focus group gave useful information about the needs and requirements from users with various disorders and contributed with other important factors to consider when designing a centered pointing device.

5.3.4 Web survey

In order to further broaden the knowledge about the products in the market it was necessary to find that information from users with experience from one or more of the existing centered pointing devices. To do this a **web survey** was put together and a questionnaire sent out to individuals that have been, or are using one or more of the devices. Their experiences and any pros or cons were asked for, and a selection of replies were received that could be used to understand more about the use of similar products. For the full questionnaire see Appendix 1.

5.3.5 Long-term use test

From the web survey a quantitative result was gathered, containing many short questions and replies. But to find a deeper knowledge about some of the products, and also to learn more about how new users adapt to and learn the products, a **long-term use test** with three test persons was carried out. The users were presented to one product each and then asked to use it as much as possible during one week. The participants were given a journal (Appendix 2) where they could record their experiences every day. The journal also had some questions that the participants filled out before the test and some questions that they filled out after the test.

The products used were Trackbar Emotion, MouseTrapper and BarMouse.

The results could give information about the initial use experience and a deeper understanding of users' acceptance of the products compared to the short informal user test performed at an early stage.

5.3.6 Interviews

Further research was made by **interviewing** ergonomists, both from Swedish occupational health service Previa, but also ergonomist Mr. Mike Fonda at Stanford University, CA, USA, and ergonomists from Ergonomics Roundtable of Sacramento, CA, USA. These experts were consulted in order to learn about their knowledge and opinions regarding the different products in the market, and also to understand more about ergonomic aspects in the work place. From the ergonomists it could also be learned more about how ergonomic aids for the work place are selected and chosen for each individual. The final design can be affected depending on whether the pointing device is chosen for the patient or if the person is allowed to choose freely.

Since not many users in the web survey or the focus group had any experience from using the Trackbar it was identified that more information about use experiences with that specifically was desirable. Therefore, **interviews** were held with three users that are familiar with the Trackbar and had used it for some time. This opened up for a deeper understanding of the pros and cons of the current model of the Trackbar.

All interviews where semi-structured and performed in an informal and relaxed context.

5.3.7 Long-term test with Trackbar Emotion

A final **long-term test** was performed where all the participants were asked to use the Trackbar during two weeks. The participants were visiting researchers at Stanford University, CA, USA and were all using computers in their daily work. All four participants were new to the product and consequently useful information about the first experiences could be gathered, as well as general preferences regarding stationary and mobile work with a computer.

After letting the participants use Trackbar for two weeks a one hour **focus group** was held where the users could talk about their experiences. To cover everything that the project team wanted, a checklist was used (Appendix 3). The open discussion was recorded with a tape recorder.

The problem definition resulted in a list of issues with the current model of the Trackbar as well as other issues with general ergonomic or usability issues with computer work. The list was then, with the help of a **KJ-analysis**, sorted and grouped into different areas. The areas represented either a user behavior or action in the computer use, or a physical area of the pointing device.

5.4 USER DEFINITION

From the extensive gathering of information to find the problem it became clear that users may be of various characters. It was no longer enough to classify them as reactive or proactive, but a deeper level of classification was done.

Due to the complexity, the users were divided into more levels to more accurately describe the different kinds of users and situations.

This user classification was important to define in order to fully understand what needs the users have, and also their preferences, requirements and so on, depending on their type of work and use of the product.

The user definition was made in collaboration with the staff at Euro Office.

5.5 USER NEEDS AND PRODUCT FUNCTIONS

To find a design proposal it was important to first understand the user needs, and from that the functions that the product should fulfill could be found.

5.5.1 User Needs

After the problem was fully understood and the users classified, the real needs among the users could be found. Once the true needs were found, they could be translated into product functions and requirements for the design proposal.

For each level of user groups the specific needs were identified and summarized based on the interviews and other research performed in the preceding stages of the process.

5.5.2 List of Functions

Based on the needs, a list of functions could be developed by simply translating the needs from each user group to a specific product function. This list of functions would later serve as a foundation for the design proposals and solutions. Since the functions stem from the user needs, a design proposal based on them would assure that the right requirements are met.

5.5.3 Personas

The list of functions proved to be rather long and complex and the functions were based on all the different users. To narrow the selection of functions down, personas were created. These were based on the different user groups and the aim was to represent the broad spectra of users that exist. Consequently the personas had very different features. They were represented with a background story including their work habits as well as a mood board.

Defining these personas helped in the further process where a priority had to be made on which functions were considered to be the most important. They were also used as an inspirational factor during the idea generation phases later on.

5.5.4 Five different approaches

The personas showed that the users are very different, and that one product perhaps not could satisfy all of their divergent needs. Therefore, based on the personas and the list of functions, a set of different design approaches was developed. They reflected different levels of complexity within a final design proposal and thereby targeting separate user groups. The five different approaches were represented with a description together with one mood board each.

From discussions with the CEO at Euro Office and based on how a final product could best fit the desired target group one approach was chosen as a foundation for the following design process.

The chosen approach affected the priority of the functions and consequently that list was revised. Based on the chosen approach and target group the list of functions was reduced to a more compact and prioritized list.

5.6 DESIGN PROPOSAL

The design proposal consisted of partial solutions, which were later assembled into concepts and finally a defined result.

5.6.1 Partial Solutions

The revised list of functions contained the main areas that needed to be solved by the design proposal. First each problem area was tended to and partial solutions to the corresponding functions were found through a brainstorming idea generation with the aids of sketching tools. The partial solutions were sketched on paper cards and after an initial screening where the less feasible ideas, that were also less probable to actually solve the important problems, were rejected, the better ones remained and were combined into a morphological matrix.

5.6.2 Concept development

Using the morphological matrix five separate concepts were generated. With inspiration from the personas and the chosen approach the differences were found through the different problem areas in the matrix. Based on an idea for one partial solution the concepts were created by putting together different solutions from the other areas.

The main elements of each concept were summarized in bullet lists and each concept was presented with sketches from various views and angles. The sketching was facilitated by the aid of inspiration boards. After the designs and functions were defined for each concept, life-size models were built using plastic foam and cardboard.

5.6.3 Concept evaluation

The five concepts were presented to the test group at Stanford University, the same individuals that participated in the two-week Trackbar test. A presentation of each concept with the aids of sketches, a model and a verbal description helped the group understand the differences among them. The participants were asked to leave their comments and feedback for each concept during an open discussion, which was also audio recorded.

The concepts were also presented to ergonomists from Ergonomics Roundtable of Sacramento, who have a different experience and preferences regarding centered pointing devices, which completed the opinions of the user groups. The ergonomists were presented to the concepts in the same manner as the user group.

These concept presentations gave valuable feedback for several of the different partial solutions among the concepts. The participants shared their opinions regarding both positive and negative sides to the different elements. All the concepts were analyzed with the feedback as a base and a list of pros and cons was created, both for the concepts and for the different partial solutions, to summarize the evaluation.

5.6.4 Concept Refinement

With the help from the concept presentations and the feedback gained from it, the five concepts were decomposed and reassembled in a new constellation. Different concepts had different positive attributes, according to the participants during the previous phase, and they were combined into one concept.

The new concept was defined with the keywords that represented it well, and sketches and models were made according to these. It was still unclear exactly what dimensions and design the concept should have, leading to two versions of the same concept. Consequently two versions of the model was built, using cardboard and plastic pipes, as well as sketches and simple CAD-renderings.

5.6.5 Concept Verification

To verify that the concept was altered correctly it was presented to the same individuals, both the test group at Stanford University and ergonomists from Ergonomics Roundtable Sacramento and Mr. Mike Fonda at Stanford University, to receive their feedback and opinions. The interviews followed the same procedure as the previous phase, with a verbal presentation of the functions and design of the concept, aided with models and CAD-renderings.

Yet again, valuable information was gained on how the design could be further improved or which parts of the current proposals that were appreciated.

5.6.6 Final Result

From the findings in the concept verification the final dimensions could be established, as well as the final design details such as rounds and other general aesthetic details.

The final result was presented with photo realistic CAD-renderings and a life-size mock-up presentation model.

6. Problem Definition

This chapter is a summary of the findings from the studies and observations. It also includes a deeper level of classification of the users.

6.1 SUMMARY OF USER STUDIES AND OBSERVATIONS

The result from all the user studies and observations (Informal user tests, Interviews, Focus group, Web Survey and Long term test) was summarized with the help of a KJ-analysis. The KJ-analysis resulted in eight different areas; Clicking, Communication, Cursor movement, Form and Ergonomics, Materials, Scrolling, Software and Usage. Each area represents either a user behavior or action in the computer use, or a physical area of the centered pointing device, CPD.

6.1.1 Clicking

Clicking is, in this report, defined as everything that has to do with the act of clicking on an object with the mouse cursor in the software. This action can be triggered in many ways and not necessarily by clicking a button.

Many people suffering from computer work-related injuries have a hard time pressing buttons, and according to Mike Fonda[1] a couple of cases where people suffering from trigger finger in the thumb, from for example grasping a regular mouse, have shown reduction in symptoms using a CPD. The participants in the focus group were keen on expressing that the clicking sensitivity is very important, for some of them every click hurts a lot and they want zero resistance. The buttons on all of the products were considered to be too hard to press, particularly on the Nomus Navigator that may be used with a healthy hand but never with an injured. To be able to customize the sensitivity of each button individually is a desirable feature for the reactive users in the focus group, in that way each user can adjust the product to rehabilitate their own personal injury.

Participants in the informal tests thought that Trackbar Emotion had too many buttons and there was a lot of confusion about what the different buttons did. One participant in the long term test pointed out that she constantly needed to look at the mouse to know where the buttons were located, something she doesn't need to do when using her MacBook's trackpad.

The two lower buttons on Trackbar Emotion were perceived, by nearly everyone, to be the primary buttons. Some participants in the long term test didn't understand their function even after reading the manual. They also pointed out that these buttons were in the way while using the other, more common functions. Users that discovered that the two lower buttons were in fact back and forward were confused since they expected the left button to be back and the right button to be forward. However, they turned out to be reversed. This setup conflict with Jordan's principles for usable design since it doesn't correspond with the users experience and expectation, at least not in western countries where right means forward and left means backward. Important to note here is that the setup has been corrected in newer models, therefore it no longer remains a problem.

To make the button setup less confusing, some users had the idea of including more functions in the roll bar, like in the track pads used on Apple laptops. One participant had the idea of placing buttons on the backside of the device and another idea was to use finger gestures instead of buttons. This would help reduce the pain caused by clicking, for the reactive user.

Many people in the informal usability tests pointed out that it was hard to use the click-function in the roll bar since it keeps gliding away every time it is pressed

Figure 6.1 The functions of the Trackbar, which caused some confusion for many users.

[1] Mike Fonda Ergonomist Stanford University, CA. Interview 2011-04-05.

down. The reactive users mentioned that the whole arm has to be used for the cursor to stay still while clicking the roll bar, something that a healthy user probably won't reflect upon.

A function frequently used by reactive users is the double-click button. On Trackbar Emotion this function is implemented in the roll bar, when the roll bar is clicked the double-click function is activated. This was not at all appreciated in the informal tests since most participants assumed that clicking the roll bar would activate a primary single-click. Many users, including Mike Fonda, pointed out that they would like to do click-and-drag-operations with the roll bar, which the double-click function disables. The staff at Previa stated that double-clicking should be avoided, because it gives peak loads in the muscles and that many models provide a button for double-clicking. Previous versions of Trackbar Emotion did not offer the possibility to click the roll bar, and therefore the staff at Previa assumed that newer versions lacked the function as well. The participants in the long term test did not realize that the roll bar was clickable and consequently didn't use it.

Participants from the focus group, informal tests and the long term test all considered tactile feedback when clicking was important. However, some of the participants in the long term test thought that the noise produced by the buttons on Trackbar Emotion was annoying and too loud, and the participants in the informal test said they felt cheap. The reactive users in the focus group liked the distinct feeling when clicking the buttons of BarMouse.

Some users wanted to be able to click the buttons with the thumbs. However, Mike Fonda stressed that it is bad to invite clicking with the thumbs.

6.1.2 Communication

This area is about what the product communicates and how it communicates its use.

The users thought that the Trackbar looked complex at first glance and would like to be instructed on how to use it correctly. The participants in the long term test pointed out that the product could be more intuitive. If the proactive user is going to use it, it has to be understandable immediately since nobody reads the manual. One person participating in the long term test plugged in the microphone cable without knowing what it was for, she just assumed that it needed to be there. Furthermore, the shape of Trackbar Emotion does not clearly communicate how the hands should be held. This turned out to be confusing to some users in the informal test.

As mentioned before, the large number of buttons on Trackbar Emotion confused some of the users and not everyone understood that the roll bar was clickable. The ergonomist at Previa pointed out that this leads to people using the product incorrectly and thereby stressing the importance of using the roll bar for clicking. RollerMouse has solved the problem with the button setup by providing small stickers for each button, telling the user what they are used for.

Participants in the focus group thought that this kind of products is very good when using word processing software or for browsing the web, but not for more advanced applications where more accuracy is needed. People in both the focus group and informal test associate CPD's with people working at a library or in a reception, but they could never imagine someone at an architecture firm using one.

Something that turned out to be positive with Trackbar Emotion compared to its competitors is that it looks portable. However, many people thought it looked like a Logitech product. The focus group disliked Nomus Navigator a lot, since it had a cheap finish and they did not even want to try it. According to the ergonomist at Previa people have very strong preconceptions about what product to use and many prefer RollerMouse or MouseTrapper.

When participants in the informal test were confronted with the question about the price of Trackbar Emotion, they said that it was probably between 1000 and 2000 SEK, and they believed that it was a product that you buy at a specialist and not at Claes Olsson or On Off. They pointed out that they believed a high price increases the credibility of the product, since it is designed for rehabilitating purposes. Mr. Fonda however doesn't believe that a high price increases the ergonomic credibility. In the US many products claim to be ergonomic and the price is just a competition.

6.1.3 Cursor movement

Cursor movement refers to the movement of the mouse pointer on the screen and everything that has to do with the input for it.

The biggest source of annoyance with Trackbar Emotion and similar products turned out to be the precision of the cursor movement, and it takes some time getting used to. It is good up and down and sideways but as soon as you try to move the cursor diagonally it gets hard. The focus group said that this kind of products limits the maneuverability; they like the freedom of using only one hand and feel limited when using both. They also pointed out that Wacom gives good control of the cursor and high precision with one hand, while the other can be used for various keyboard shortcuts. People answering the web

survey also pointed out that the roll bar doesn't have the same high precision as the trackpad of a laptop.

The focus group stressed that it is important that the roll bar follows the finger movements. Uncomfortable friction against the fingertip, like on a trackpad, is not desirable. The users from the informal test liked how a roll bar follows the hand, they also liked that it is heavy and frictionless. However, some people thought that it was hard to control the cursor, since it requires fine motor ability.

The roll bar spins around an axle and the cursor can be moved infinitely up and down, but moving the cursor sideways is limited by the length of the roll bar and the width of the device. Therefore the cursor has to reset when reaching the physical boundary (Fig. 6.2). Many users didn't reflect upon this and were annoyed when it happened, particularly on Trackbar Emotion since it doesn't give any feedback, other than on the screen, when it resets. On the competitors there is a click and the cursor resets with the help of a switch, allowing the feedback to occur simultaneously. On Trackbar Emotion it is controlled by optical sensors, and the cursor resets before the bar hits the end, which causes confusion.

Figure 6.2 The roll bar hits the ends which causes some frustration among the users.

Another thing that annoyed users was that it was impossible to move the cursor while the roll bar is pushed down, making it impossible to drag and drop objects. This probably has to do with the double-click function of the roll bar rather than any physical limitation.

The ergonomist at Previa recommends having a long, wide roll bar. Just like the new improved RollerMouse Free (Fig. 6.3), where the roll bar can be reached from anywhere thanks to the long roll and the open design. Users participating in the web survey wanted a wide area for the roll bar, so the cursor has a large area of motion. They also preferred the steering pad of MouseTrapper over the roll bar of RollerMouse, when it comes to precision.

RollerMouse has a switch that makes it easy to change the sensitivity of the cursor without any software. This is good, because users have different sizes of screens and

Figure 6.3 The RollerMouse Free has an open design of the roll bar, which makes it easy to access.

different screen setup. When using two screens it might be preferable to be able to change the sensitivity in a quick and easy way.

According to Mr. Fonda, the entire use of a mouse pointer should be avoided because it involves awkward postures, repetitive movements and micro manipulations with the fingers.

6.1.4 Form and ergonomics

This area involves the shape of the product and the ergonomics of its use.

The height of Trackbar is an issue to many users, it results in tilted wrists in uncomfortable angles. The ergonomist at Previa said that tilted wrists are bad and for that reason flat keyboards are preferable. Mr. Fonda also pointed out that Trackbar Emotion could benefit from a more shallow design.

The users participating in the long term test thought that Trackbar was too big to be portable and none of them brought it home from the office due to its size. One of the users had a MacBook Air which has a really thin front edge and for her there was no point in using the Trackbar at all since it only got in the way and she already had all the functionalities, plus more, in the trackpad of her laptop. Furthermore, the trackpad is close to the keyboard and allows her to keep her hands centered and still at all time.

One of the reactive users in the focus group had really big hands. Therefore he stressed the importance of considering different hand sizes and the buttons should not be placed too close together. He had to twist his wrist in an unnatural way when using the device and he did not like that the product required such high motor ability in the fingers to control. Some people answering the web survey had experienced wrist pain when using RollerMouse, but it had disappeared after switching to MouseTrapper.

There were some differences of opinion regarding the hand support provided by Trackbar Emotion. Some users in the informal test liked the support and said that it was good while others said that it was uncomfortable when typing on a keyboard and that it was not wide enough to give support for people with broad shoulders. One of the users participating in the long term test liked Trackbar because of its support, she was using it with a stationary computer and it gave her good support while typing on the keyboard. See Figure 6.4 for a comparison of thick and flat keyboards. Some people in the web survey complained about using RollerMouse in combination with new thin keyboards, they did not like the angle of the hands. Others liked the support of MouseTrapper because it was soft and comfortable to rest the hands on.

Figure 6.4 Trackbar used with a regular thick keyboard (top) and with a flat keyboard (bottom).

Many people preferred Trackbar's larger diameter of the roll bar, compared to the one of BarMouse. It's good with a big surface and the radius is inviting. Furthermore, Mr. Fonda believes that the larger diameter reduces the micro manipulations in the fingers.

When using a CPD in combination with a laptop the distance from the mouse to the keyboard becomes an issue (Fig. 6.5). It results in a constant hand movement back and forth, which mostly occurs during typing work, where the user constantly needs to use the cursor to highlight text or move around in the text masses.

Figure 6.5 Using Trackbar with a laptop causes a lot of reaching.

One of the users in the long term test got used to the distance after some use, but the ergonomist at Previa stressed that it's not good to move the hands back and forth between the keyboard and the mouse. "It's like a rope that wears in the shoulder", she said. The users in the focus group put their Wacom tablets on top of their laptop so they don't have to reach that far while typing. One of them said that she would probably do the same with this kind of product.

Even if the CPD is used with a conventional keyboard, reaching can't be fully avoided, and they don't fit ergonomic keyboards, which usually have a curved front edge. (Fig. 6.6)

Figure 6.6 An ergonomic keyboard with a curved front make the CPD:s fit badly and cause a distance.

According to the ergonomist at Previa, Trackbar Emotion is deeper than the RollerMouse which results in a greater distance between the roll bar and the keyboard. One user in the long term test would have preferred a more integrated product, which would mean to avoid separating the keyboard from the mouse; a CPD-keyboard.

Participants in the long term test found the cable of the Trackbar too long and therefore not convenient to use with a laptop. However, as opposed to conventional mice a CPD saves space on the desk since it doesn't have to be moved around on the table.

The symmetrical design of Trackbar Emotion enables use with either one hand or both. The flexibility is good but the Previa recommends using both hands together, which is also the most effective way to use a CPD according to experienced users. The ergonomist also pointed out that the mouse should be centered in front of the body and support for the forearms should be provided.

The choice of product is very individual according to the ergonomist at Previa. Since everybody has different biometrics they also have different preferences. Most users are satisfied with what they already have and can't see any reason to change to another product. One user answering the web survey said that switching to a competitor would not be an alternative without talking to an ergonomist first.

Trackbar can be used in a rotated direction, turned around 180 degrees, Figure 6.7. Mr. Fonda considers this

to be a good feature; together with the convenient size it makes the product flexible. Some users in the informal test found it comfortable to use it this way, but no one in the long term test liked the idea; the edge was too high and steep against the hands.

Figure 6.7 The Trackbar can be used backwards, which can be a good feature.

6.1.5 Materials

This area includes findings about the materials of Trackbar emotion and associated products.

Many participants in the informal test expressed that the materials of Trackbar were not as nice as they had hoped. The plastic exterior made it feel cheap and the noise produced by the roll bar hitting the ends adds to that. The ergonomist at Previa stressed that it was an important factor to consider, particularly in office landscapes. Another thing people thought add to the feeling of low quality is the glitches and bad fit of the buttons, and the blue color of the Trackbar buttons looks like some kind of protective film, used for protection during transport etc. The roll bar on the other hand was very much liked since the weight and the comfortable rubber material on the surface added to a feeling of high quality.

Some users believed that the material of the arm supports could have been softer and Mr. Fonda said that a softer surface material might be beneficial if it reduces the pressure on the arms. The architects in the focus group had the idea of using some kind of leather like on an exclusive piano stool.

MouseTrapper has a softer material as hand support, but many people in the survey complained about this because it made the product difficult to clean. They also mentioned that the steering pad and buttons collect dust. These factors combined make the product feel unhygienic.

According to an experienced user in the focus group, RollerMouse is a very high quality product with high durability and she really liked the materials. However, one user from the web survey mentioned that the roll bar may break after using it a lot.

To provide a comfortable surface to the product the Trackbar team developed silicon sleeves (Pic. 6.8). The sleeves come in different colors to fit the users' preferences. Some users liked them because they could be changed as soon as they became dirty and it would facilitate the cleaning of the device. Others did not like them because they might collect dirt or make the hands sweat. None of the users in the long term test used the sleeves, one because when she tried to attach it she realized she had missed to plug in the cables and after that she gave up. One person thought that the material of the sleeves would make the arms stuck, and not glide easily over the surface while typing. The ergonomist at Previa did not like the sleeves because of the same reason, there's simply too much friction.

According to the ergonomist at Previa colors should not be too bright or too dark, dark colors increase the contrast between white paper and bright screens that our eyes shift focus between. She recommended that matte silver could be used.

Figure 6.8 The Trackbar with a silicone sleeve.

6.1.6 Scrolling

Just as Clicking and Cursor Movement this area has to do with the action scrolling within the software, but it also includes physical attributes about the scroll function.

Many complaints regarding the scroll wheel of Trackbar Emotion came from the informal test participants. They found the scroll inert and the motion was very slow. The difference between the roll bar and scroll wheel was very

big. They also posed the question of why there should be a scroll wheel at all when there already is a roll bar. This also came up in the long term test where the users thought it would be very nice to scroll with the roll bar. However, users participating in the web survey stressed that the scroll function of MouseTrapper, which is integrated in the trackpad, was very hard to find and unintuitive to use. Some people didn't even know that it was possible to scroll at all.

Furthermore the steps in the motion of the scroll wheel of Trackbar were both liked and disliked. The scroll wheel was often accidentally clicked due to the steps but also because of the low material friction and inertness; the low friction makes the fingers slip while scrolling, resulting in an accidental depressing of the wheel. However, users in the web survey said it's important that the scroll wheel is clickable.

Some people considered the scroll wheel to be inaccessible and they did not like to scroll with the thumbs.

6.1.7 Software

This area is about how the device is associated with different types of software in the computer.

The participants in the focus group were very keen on expressing that the device should be fully customizable. They requested the possibility to program each button to any keystroke individually, and if possible, having application specific settings would be even better. A parallel to Wacom tablets, where everything can be customized including application specific features, was drawn. Participants in the informal test wanted customizable buttons as well and they stressed the importance for it to be fast and easy. From the web survey it dawned that office workers can't program functions on their MouseTrapper because of administrator rights. And none of the users in the long term test downloaded the software for Trackbar, which was also their impression of users in general; "Nobody wants to download software". They also said that in many workplaces the employees have to go to the IT department to be allowed to download the software, and few people do that.

A problem with Trackbar Emotion is that there is no software for the Mac OS X interface, for example the two lower buttons doesn't work at all.

One user in the focus group had been using voice controlled software called Dragon Dictate, he thought that it was good but it was important to have a good microphone with noise reduction and he could see no reason to have a built in microphone in the device. People in the long term test thought that it would be very annoying to use the voice control in an office space, hearing people speak to their computers.

Furthermore there is a software that forces the user to take breaks every fifteen minutes, one user in the focus group had used it and said it was very effective.

6.1.8 Usage

This area involves what the product is used for.

Trackbar proved to be good for web browsing when only the mouse is used, but users would much rather use a conventional mouse for graphic design, playing games and CAD-work. Many users think the device is annoying to use with word-processing software since it's in the way in most cases, or forces the user to constantly reach back and forth. Others said that it's probably very useful for database applications. One user said that several products have to be used; Wacom and mouse for graphics and CAD and Trackbar for everything else.

6.2 EMG TEST

In the informal tests it was observed that almost everyone used Trackbar with only one hand, which raised a concern whether it was bad to use just one hand. To get a better understanding of how the product affects the muscle activity in the arm the Trackbar was tested with both one hand and two hands (Fig. 6.9). It was also compared with MouseTrapper and a conventional mouse to see if any differences existed.

As can be seen in the diagrams below (Fig. 6.10) no significant differences in using Trackbar with one or two hands can be found. However, according to the ergonomist at Previa, CPD's should be used with both hands to allow variation. And using Trackbar with one hand could force the hand to be held in uncomfortable postures.

As seen in Figure 6.11 some differences in muscle activity between the conventional mouse and the CPD's can be found in the upper arm; deltoid and trapezius muscles. However no significant differences between Trackbar and MouseTrapper can be found.

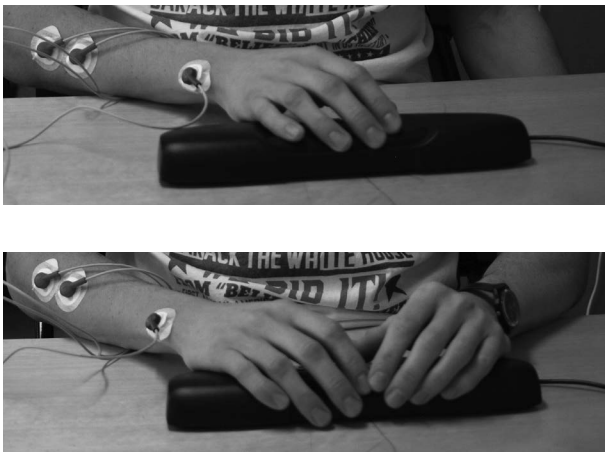


Figure 6.9 EMG-measures were made both using one and two hands.

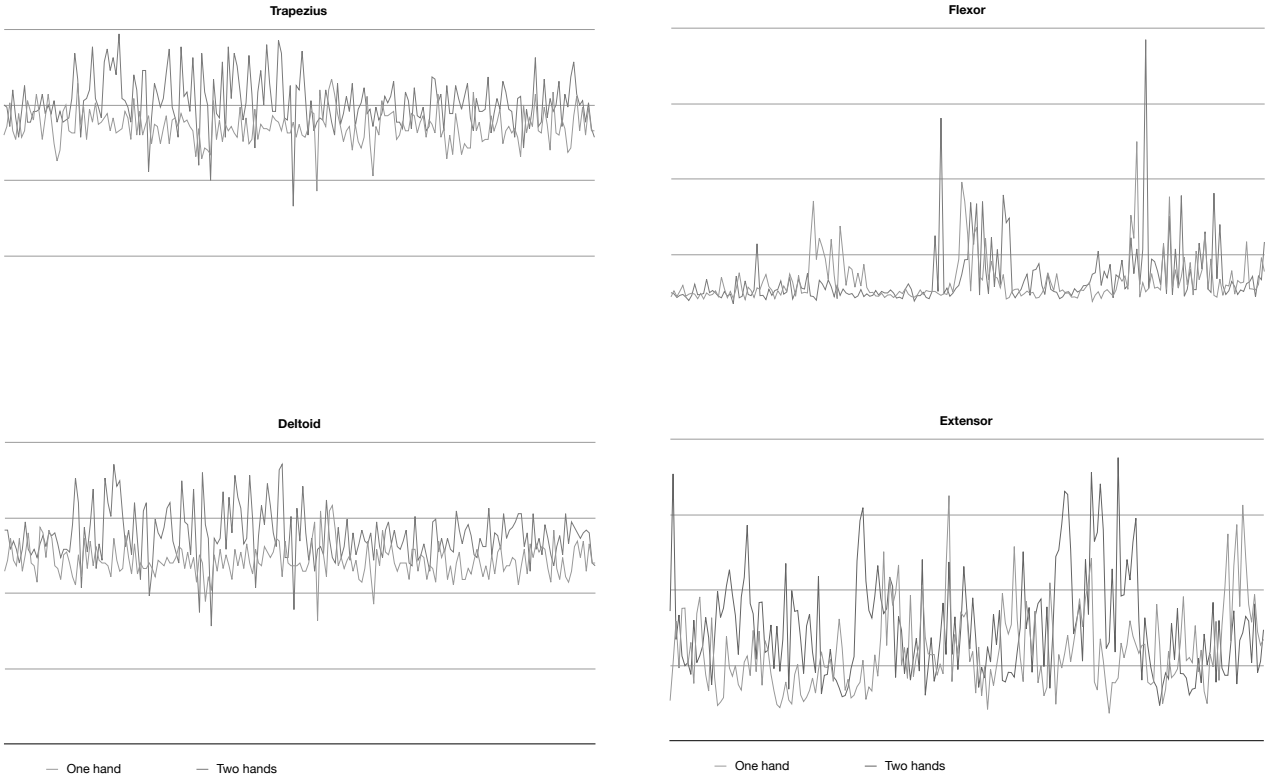


Figure 6.10 The measures showed no signifant difference for the two postures.

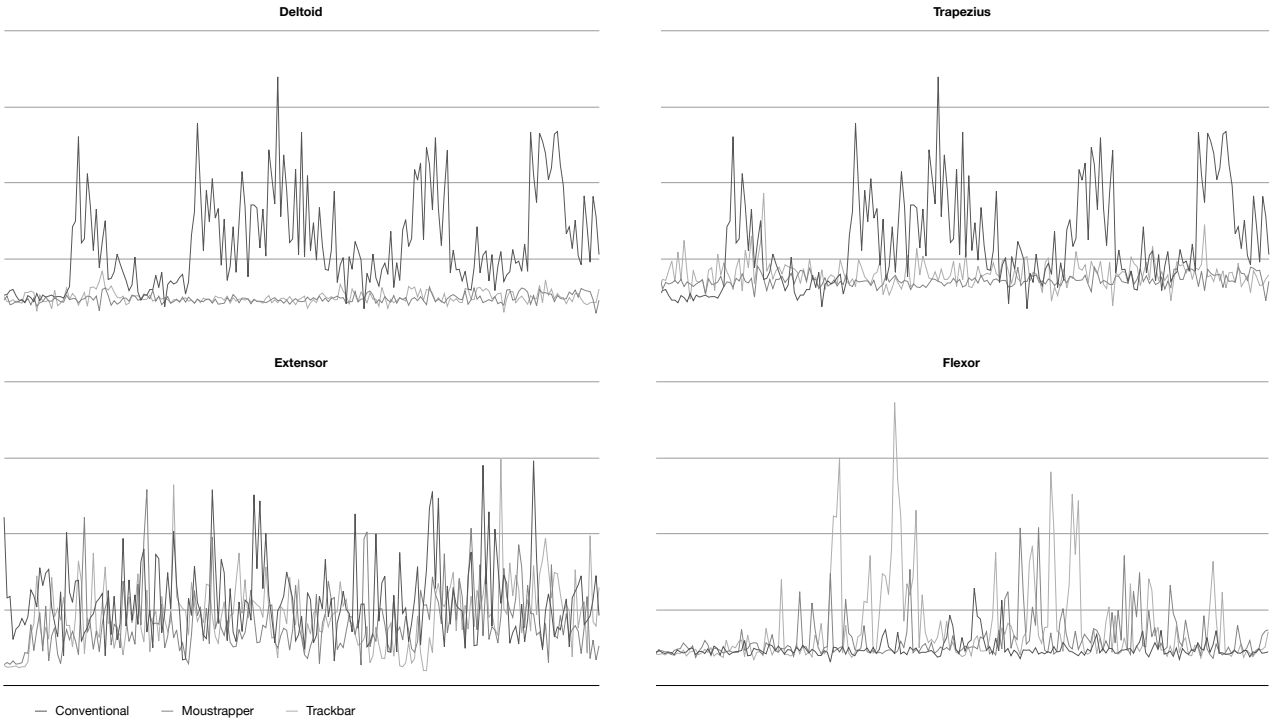


Figure 6.11 The measures showed no signifant difference for the two postures.

6.3 CATEGORIZATION OF USERS

To understand user needs and to be able to consider different aspects depending on the type of work the users perform, a hierarchical categorization follows below. Each level in the hierarchic structure has its own driving force which determines the categorization type.

6.3.1 First level - Intentions

Here users are sorted according to their intentions of use.

Reactive users
The reactive users are individuals that experience pain, numbness or other types of discomfort that come from extensive mouse use. They seek a device that will help them in their rehabilitation process.

The needs that come from the reactive users are very important to meet, since they are a critical user group that really needs an ergonomic device that helps. The product won't fulfill its main purpose if it doesn't satisfy the reactive users, no matter how good it is in other aspects. Therefore other aspects beside the ergonomic benefits are of less importance.

Proactive users
The proactive users consist of people who want to prevent future injuries by using ergonomic alternatives. This user group may find the product and choose to buy it in a retail store or by consulting health care services or a doctor.

A proactive user understands the benefits of a centered pointing device from academic or medical research which proves the benefits and builds up a high credibility for the entire product category.

6.3.2 Second level - Motivation

The next aspect to consider when categorizing a user is the motivation, which may vary depending on whether the product is used by own will.

Voluntary users
The voluntary user actively chooses to try an ergonomic alternative and has a high motivation to use and adopt it.

There may be many reasons for a voluntary user to switch to an ergonomically beneficial pointing device. For example lots of people realize that friends, family or colleagues in their surrounding suffer from mouse arm (or related disorders). Fear of ending up with the same problems lead to a strong motivation to prevent that situation.

Involuntary users
An involuntary user can't affect the decision to use the product and has a low level of motivation to use it. The device can be assigned to the user by for example the

employer, where the company has an ergonomic policy or because of the existing work place layout. Involuntary use could also include an individual with such serious symptoms that no alternatives but using the ergonomic device remain.

6.3.3 Third level - Context

Users may find themselves in several different work contexts, which highly affect the demands on the product. A significant division can be made separating mobile users from stationary ones.

Mobile
The mobile users are people who travel and work from different places all the time, and primarily use laptops. Furthermore their workplace layout differs from time to time.
Stationary
As opposed to the mobile users, stationary users have a fixed work place with a proper desk, chair and most likely a desktop computer with separate keyboard and screen.

6.3.4 Fourth level - Type of work

At the final level the differentiation factor is the type of work the user performs. There are endless different works and professions for all computer users, but one distinctive classification can be made on the level of precision, and consequently how the pointing device is used.

High Precision
High precision work includes advanced computer work such as graphic design, illustrating, video editing, CAD-work, audio editing, computer games etc. For all the above, plus of course several other similar work types, it is crucial with high precision of the cursor movement, both high speed and acceleration as well as fine detailed movements. Furthermore it is important that a high efficiency in the work can be maintained at all times.

The common denominator is the frequent inputs that are required and particularly the need to use both cursor and keyboard input simultaneously.

Standard Precision
Standard precision work means computer use where less complex software is used and the user focuses on either typing and using the keyboard or using the pointing device. It means the mouse and keyboard use is alternating, as opposed to simultaneous. It is important to remember that this type of work also may require maintained work efficiency.

Examples of standard precision work is typing, spreadsheet management, database handling, business systems, web browsing or coding.

6.3.5 Special needs

There are certain areas with special needs where the technology in the Trackbar could be beneficial to use, such as within health care, hospitals or aircrafts (pilots etc.). These areas are however too specific to be included in the main target group of users.

6.4 SUMMARY OF PROBLEM DEFINITION

To summarize the problem definition, the problems with Trackbar found through the research are listed in the bullet-list below.

- The sensitivity of the buttons are usually not sensitive enough.
- Users thought that Trackbar has too many buttons and that the layout was confusing.
- Functions of buttons are not compatible with users' expectations and earlier experience.
- The click function in the roll bar is hard to use because it glides away.
- Double-click function in the roll bar does not confront with expectations.
- Impossible to click-and-drag with the roll bar.
- Cheap feeling in the buttons.
- Looks difficult to use and users wants to be instructed.
- Not good for advanced activities such as CAD and graphic design.
- Associated with librarians.
- Looks like a product you buy at a specialist for rehabilitating reasons
- Cursor is difficult to control and has bad precision.
- The cursor resets before the bar hits the end without giving any feedback.

- Impossible to move the cursor with the roll bar pushed down.
- Trackbar is too high for flat keyboards and too big to be portable.
- Needs high motor ability in the fingers to control.
- Uncomfortable support while typing on keyboards.
- Not wide enough to support arms of people with broad shoulders.
- Huge distance between mouse and keyboard on a laptop.
- Does not fit ergonomic keyboards.
- Trackbar's cable is too long.
- The plastic exterior combined with the quality of the buttons makes the product feel cheap.
- Material of arm support is hard.
- The material of MouseTrapper's support is hard to clean.
- Too much friction in the sleeve material of Trackbar.
- Too inert scroll wheel.
- Scroll wheel gets accidentally clicked while attempting to scroll.
- No software for Mac OS X.

Some other important factors to consider are listed below.

- More functions could be included in the roll bar.
- A double-click button is important to provide.
- Tactile feedback when clicking is important.
- It is important to be able to use the roll bar for clicking.
- Portability is a competing advantage.
- It is important that the roll bar follows the finger movement.
- It is good to be able to reach the roll bar from everywhere.
- A large area of motion for the roll bar is good.
- Being able to change the sensitivity quick and easy is good.
- Different hand sizes need to be considered.
- The radius of Trackbar's roll bar is good and inviting.
- People might put their device on top of the laptop.
- A CPD should be used with both hands.
- The choice of product is individual.
- A good feature to be able to use Trackbar in a rotated direction; 180 degrees.
- The roll bar of Trackbar expresses quality.
- The sleeves for Trackbar can be good for hygienic reasons.
- Colors should not be too bright or too dark.
- Scrolling could be performed with the roll bar.
- There is a demand for customizability.
- There is no reason to have a built in microphone in the device.

7. Function Definition

This section explains how the problem definition was transformed into user needs and then personas in order to choose an approach for the final design. The chapter results in a list of functions that is used as a foundation for finding solutions in the next phase.

7.1 NEEDS

To find the user needs each user group was analyzed and compared to the problem definition. It could be determined which problem stemmed from which user group and thereby the problems could be translated into needs. However, it became clear that not all problems are related to a specific user. They could also be connected to a phase in the life cycle of the product.

Following is a description of the needs of each user group, but also a classification of use phase dependent needs.

The main needs that have to be fulfilled for any centered pointing device regardless of user or phase are:

- **Cursor control** - Provide control of the cursor on the screen
- **Click input** - Transfer the main click functions to the software as primary and secondary click (usually defined by the left and right mouse buttons respectively)
- **Page scroll** - Scroll function to easily scroll through documents and websites. The scroll function is not limited to up and down motions but also includes scrolling 360 degrees.

7.1.1 User Needs

First level - Intentions

Reactive users

Reduce pain - It is important that the product reduces whatever computer-related pain the user may experience. Therefore the product needs to:

- Facilitate support for the arms, either by external products or by providing it in the design
- Facilitate a neutral working posture
- Reduce click-stress

Provide flexibility - Pain may also be reduced by using both hands or switching between them, therefore it is important to *provide two-handed navigation*.

Provide individualization - Injuries differ from user to user, and there is an expressed demand for *customization possibilities* of the buttons, not only the buttons functions but also their sensitivity.

Physical size is also something that differs from user to user. A user with big hands may experience problems with fine motor abilities and a user with small hands may have problems reaching. Thus there is a need for the physical size to fit a large span of hand sizes.

Provide ergonomic credibility - For a reactive user the decision of which product to choose is often made while consulting an ergonomist. The ergonomist display many alternatives that are equally good when it comes to ergonomic attributes, and the user chooses from these. Therefore it is important to express credibility, both in order for the ergonomist to choose to have it on display in the *ergostudio*, but also to help the user choose the specific product.

Give feedback - When clicking a button feedback is important. Instant tactile feedback lets the user know that the button has been pressed hard enough and that no more push force is required.

Proactive users

Comfort - In order to fulfill the needs of the proactive user the product has to be comfortable to work with. This concerns the size and the materials of the product. It is important that it is comfortable, both while using it to control the cursor and while typing on the keyboard.

Design - The physical design of the product is important in order to increase new users' interest. Proactive user's main priority may not necessarily be the ergonomic benefits, but for these users the pointing device also needs to match the rest of the computer equipment.

Usability - In order for the user to learn a device, good usability is important. That means the learning curve should be short and thus no effort to learn how to use the functions should be required.

Furthermore guessability is important for the proactive user. Functions should be operated in the way the user expects and consequently an intuitive interaction can be achieved.

Quality - For the proactive user it is important that the product has a high quality and lasts for a long time. The quality also affects the product's credibility and the user is more likely to experience a satisfaction.

Ergonomic credibility - As for the reactive user, the credibility is important to consider. The user won't choose a cheaper product unless it provides sufficient credibility.

Second level - Motivation

Voluntary users

Learning Curve - The voluntary user is willing to learn, therefore a learning curve is accepted.

Involuntary users

Customizability - In many offices the employees don't have admin control and can't customize the functions of the buttons by themselves through software. Consequently it is important with good default configurations.

Third level - Context

Mobile

Portability - Since they are on the move it is important that the product is portable, that is lightweight and small, as well as easy to connect.

Laptop use - They have a need to use the pointing device with a laptop.

Versatility - The mobile users use the pointing device to perform many different tasks, it is therefore important to consider the versatility. Since the product needs to be portable the user doesn't want to bring several devices but instead minimize the weight and volume of products to bring.

Stationary

Desktop computer use - The product is used at a desk and needs to fit desktop computers with conventional keyboards.

Fourth level - Type of work

High Precision

High Precision - Advanced users require high precision and high efficiency to be able to perform their work. Almost no learning curve when it comes to maneuvering the cursor is accepted.

Keyboard shortcuts - The use of shortcuts is essential for the advanced user which leads to the need of controlling the cursor with one hand while using the shortcuts with the other.

Customizability - The advanced user wants the buttons to be fully customizable. For example different functions for the buttons depending on the software.

Use with dual screens - Graphic designers and CAD engineers use dual screens a lot and need the product to fit a dual screen set up.

Standard Precision

Precision - The precision needs to be sufficient for the user to be able to perform his/her work without slowing down the work flow.

Multiple clicks - Series of multiple clicks are often used in word processing and database software. For example three clicks are necessary when text in a table cell is to be highlighted.

7.1.2 Contextual Needs

The product has to fulfill different needs, not specific to the user, in the different phases of the product life cycle. The aspects important to consider in each phase are presented below.

Point of sales

Through an ergonomist
Factors influencing the choice of product:

- The ergonomist's personal preferences
- The models provided
- Differentiation from other products
- The design of the product
- Personal preferences of the injured person
- Usability
- Quality
- Ergonomic credibility

In a store
A proactive user who wants to buy an ergonomic pointing device has to either visit an ergonomist or buy it online. However, centered pointing devices will most likely also be sold at consumer electronic retailers as well. This will expose the product to a wider range of users and the customer is probably also the consumer of the product.

Factors influencing the choice of product:

- Differentiation from other products
- The design of the product
- Quality. For example the product needs to be quiet and not make bulky sounds.
- Ergonomic credibility

First time use

The first time use could take place at an ergonomist's office, at a store or at home after the product has been bought.

Factors influencing the users opinion of the product are:

- Usability and pleasure of use - guessability
- The materials and the haptic feeling they provide
- Comfort

Long time use

During the long time use phase other factors become important such as:

- Cleanliness - how easy it is to keep clean
- Quality and durability

7.2 COMPLETE LIST OF FUNCTIONS

By translating the needs from each user group to a specific product function a list of functions could be developed. This list serves as a foundation for the design proposals and solutions. Since the functions stem from the user needs, a design proposal based on them will assure that the right requirements are met.

Below are the most important functions listed, the complete list of functions can be found in Appendix 4.

- **Replace mouse** - The product should have the same functionality as a conventional mouse since it is supposed to replace it, i.e. move the cursor, enable left- and right-click and enable scrolling.
- **Allow hands to operate in a centered position** - The main principle of a centered pointing device is to operate it with the hands comfortably centered in front of the body.
- **Reduce click stress** - It is common to experience pain while clicking due to high peak loads, and multiple repetitive clicks may cause injuries. The click stress may be reduced by reducing the number of clicks, i.e. avoiding double- and triple-clicking, and by reducing the clicking sensitivity.
- **Allow flexible use** - An important ergonomic aspect is the ability to be flexible, i.e. use the product with either hand.
- **Be portable**
- **Provide efficiency in use**

7.3 PERSONAS

The list of functions is based on all user groups and use phases, and provides a very wide selection of functions. In order to find a solution that is feasible and targets the correct users, the selection of functions had to be narrowed down. Therefore, four personas were created based on the different user groups with the aim to represent the broad spectra of users.

On the following pages are descriptions of each persona together with their photo and a moodboard.

In-house event coordinator
Age 55

User type:
- **Reactive user**
- **Voluntary use**
- **Stationary work**
- **Standard precision work type**

Work station:
- **Stationary computer**
- **Conventional flat screen, keyboard and mouse.**

ELISABETH CONNOR

'Liz' Connor lives in the suburbs of a big city in a mid 20th century country style house with a small garden. She lives with her husband Casper whereas their three children, aged 21, 23 and 27 have moved out. Liz loves her garden and tending to her small collection of roses takes up a lot of her spare time. During the colder seasons, when the garden isn't blooming, she likes to paint with oil on canvas, mostly flowers, but also landscape sceneries.

From her home, Liz travels by car to her work every day, which is located close to the city center. Liz's work consists of coordinating and arranging in-house seminars, meetings and events, both for the company's employees, but also for various guests and clients. Therefor it is important that she is able to communicate with many stakeholders, both external customers internationally, but also internally to financing and organizational departments. Liz compiles memos, briefing emails, invitations and performs some budget calculations in spreadsheets. Occasionally she needs to prepare presentation material like keynotes or powerpoint slides. Liz handles the computer equipment well, but is definitely not interested in learning many functions, and she has a hesitant and resistant stance towards technology in general.

Liz meets a lot of people, but also works several hours in front of her desk every day, where a stationary computer has been provided to her. From years of working at non-beneficial work stations and also from her hobby taking care of her small garden, cutting flowers, she has developed discomforts in the shoulder region which often turn into flashes of pain.






Interaction and web designer
Age 26

User type:
- **Reactive user**
- **Voluntary use**
- **Stationary and mobile work**
- **High precision work type**

Work station:
- **Laptop with docking station**
- **Extra keyboard and mouse at work**
- **Dual screen setup**

JAKE BICKERTON

Jake has been a frequent computer user for many years, when he was 13 he started to take interest in web design and created web pages for himself and his friends. At the age of 22 he started working as an intern at a web production company. Today his work mainly consist of graphic design with a small amount of programing. Jakes type of work requires him to use the keyboard and mouse simultaneously. One hand handles keyboard shortcuts, required for an efficient workflow in his graphic design application, while the other is controlling the mouse cursor.

He started to experience pain sometime around the age of 21, however he didn't realize that the pain was computer related until he met people with similar problems two years later. This was also the time when he started to experience so much pain that it prevented him from performing the work he loves. Jake is very dependent on his computer work and needs to be able to perform it without straining his arm any further.

In his teenage years he spent many hours playing video games, when he grew older his interest for video games was replaced by an interest in culinary art and fashion. Since he's not playing that much video games anymore his competitive genes are stimulated by watching European soccer with his friends, preferably at an Italian sports bar. Although his never been much of a ball sports player himself, he enjoys playing soccer with his friends once in a while just to get the exercise.


Schneider-KREUZNACH
TRADIZIONE E NATURALITÁ
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Customer Service Representative
Age 29

User type:
- **Proactive user**
- **Voluntary use**
- **Stationary and mobile work**
- **Standard precision work type**

Work station:
- **Stationary computer with an advanced telephone set and head-set.**
- **Or: laptop with built-in trackpad**

KAREN WU

Karen lives an active life in a big city, where she meets lots of people during various social events. Her apartment is situated on the seventh floor, and has a small balcony facing south-east. During the recent years Karen has connected with eastern philosophy, and therefor spends a lot of time meditating and doing Yoga classes. Apart from that she tries to eat healthy and stay away from fast-food, alcohol and other degenerative temptations.

On the weekends Karen has a so far unpaid hobby where she writes for a Health&Fitness blog, and occasionally her column is published in the printed version. She loves to spend a couple of hours sitting at a café, drinking herbal green tea, while she writes the column on her laptop.

During the weeks Karen works as a customer service representative, replying to customer requests and inquieries over telephone and emails. Her work station consists of a stationary desktop computer with good choices for adapting it to each worker's indivudal needs.

Karen knows that working several hours in front of a computer every day means big risks of developing various disorders, and therefor she is very cautious regarding her health situation, and she does what she can to prevent any undesirable situation.

Middle manager, IT
Age 45

User type:
- **Reactive user**
- **Voluntary use**
- **Mobile work**
- **Standard precision work type**

Work station:
- **Varied context with netbook**
- **Wireless bluetooth mouse**

William McAllan

William is a middle manager at an IT-company, he performs most of his computer work between meetings on his Netbook. He is always on the move, working from the train or at an airport café waiting for his next flight to depart. His time at the computer he spends writing emails and reports as well as preparing presentations, he also does a small amount of spreadsheet work.

William has never been a hardcore exerciser, this combined with a bad working posture and a stressful job has during the years contributed to pain in his neck, shoulder and upper arm region.

Technology and gadgets have always played a big part in Williams life and he is never late to get the newest computer accessories. Besides following the evolution of technology, William enjoys having a big glass of stout with his best friend Pete. The family is very important for him and he tries to spend as much time as possible with them in their Townhouse. Baking bread and playing parlour games on friday nights brings the family together, according to William.


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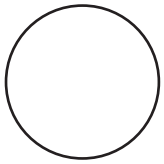
378 145

7.4 DIFFERENT APPROACHES

The diversity of the personas, which reflect the real users, show that the solution has to fulfill many different needs. Finding one product that could fulfill all these needs would be complex, and therefore five different approaches were developed. They showed different levels of complexity, where a simple one would satisfy the needs of a basic user, whereas the most complex one would have large potential and functions to satisfy the most advanced users. The approaches are presented with a moodboard and an icon respectively.

SIMPLE



The simplest approach, where the most necessary functions are included. Only the basics are represented in order to fit the least advanced user with little interest in technology. The idea is to provide a small and very portable product that is really easy to use, with only the primary functions and thereby offering limited potentials.

The simple approach fits the users with very low needs regarding advanced functions. These users are not interested in technology and only want a really simple product that is as easy as possible to learn. The simple approach, thanks to its portable features, is also suitable for the very mobile users.

BASICALLY BASIC

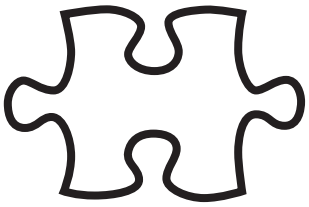
This is a basic approach where the necessary functions are completed with some more elements that improve the potentials of the product. It means that besides from the primary input methods there are more ways of interacting with the computer. This is a simple product but it has some features that make it fit users that want to be able to operate on a moderate level. It is allowed to be larger and more complex, both in terms of functionality and shape.

Many users do not need any advanced features, but do work with software that require or endorse the use of shortcuts. Through the basic approach users will have a simple product but with the possibility to perform some more advanced input methods. The product will give the users a short learning curve, but for those with higher interest in learning more, the potential allows them to do so.



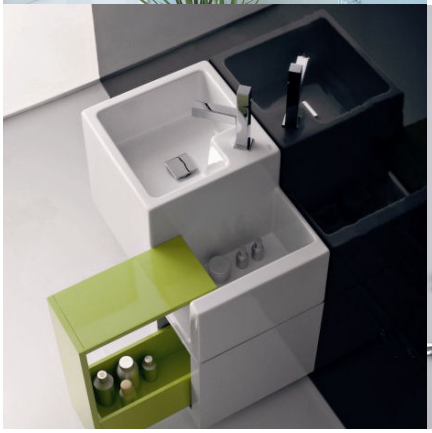


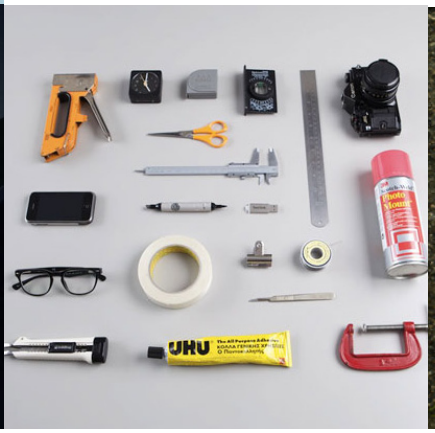
More Modules



For the module based approach the product has basic functionalities in a main part, to which other parts can be attached to increase the level of functions with user specific needs. It means that each user can choose which functions are desirable and the product can consequently be customized to fit many users on their own individual level.

The module based approach fits users with versatile work places, that need to adapt the product to the current situation. The module based approach also fits many different users with different needs, and can be adapted to each individual. This requires that the users understand the potential of the product and are interested enough to learn about the system.





NGENIOUS NTEGRATION

The mouse operations and the keyboard inputs will be integrated into one product in this approach. It will allow the user to make all inputs from only one product where all the elements are closely located and always in reach.

This approach will lead to a rather large product which makes it useful for stationary users and not for the mobile users. It may also cause the product to be more static and less flexible which blocks out some very demanding users in terms of an adaptable device.

All Advanced

The most advanced approach has lots of functions for the advanced user, a user that demands high input frequency and uses lots of keyboard shortcuts. With the advanced approach the user is able to let go of the keyboard as long as other tasks than typing are involved. With many input options, customizable configurations and high-tech solutions, this approach will demand a lot from the user's understanding and interest, but in return give a versatile input selection.

This leads to a far too complex product for the users that are not technologically interested, and consequently they will have a hard time adopting it.

7.5 CHOICE OF APPROACH

Together with the CEO at Euro Office, Mike Sjoblom, the approaches were discussed and analyzed in order to find a way to proceed. Since the users are very diverse and difficult to generalize it is important to fit the product to as many users as possible. That could be achieved by choosing a simple solution that will be usable by a large group of individuals.
Below are some comments on the different approaches.

Ingenious Integration would mean a completely new product, that might be expensive and difficult to construct. However, that could be solved by first defining a basic version and from that expand it to an integrated model.

In order to make the *All Advanced* approach it would require more user studies for the actual advanced users. They probably have several needs that are very specific to their work, and thus finding one advanced model would perhaps not fit a majority of advanced users. For the advanced users the products might require highly customized features.

For a majority of Trackbar users the *Simple* would fit well, thanks to its ease of use, it is however very restricted in its potential for extra features and functions. The *Basically Basic* model might be a better mix of simplicity and extra functions for many users.

The simple and basic models could be combined somehow to profit from the ease-of-use in the simple one, but simultaneously take advantage of the bigger potentials of the basic one. The more functions that the basic approach mean may however not interfere with the ease-of-use in the simple one.

With *More Modules* it seemed, after some discussions, that no user would really be satisfied, but the finished product required various add-ons in order to fulfill a user's needs. Also, it would make the use experience complex and advanced, and require some skills from the user to understand how and why to use the different add-ons.

Based on the observations above it was decided to find a solution that is very basic and simple in its default state, but at the same time provide some extra functions that increase its potential for advanced users.

The final decision was consequently that the product should be simple and easy to understand and use, in order to attract and fit as many users as possible. However, not to exclude the more demanding and advanced users, there should be more potential in the device. That can be achieved by including extra functions, that may be activated or customized according to the user's preferences, but never to the extent that it interferes with the basic user's interaction.

7.6 REVISED LIST OF FUNCTIONS

The choice of approach made the list of functions excessive and could therefore be narrowed down accordingly. Some functions could be removed and the ones correlating to the simple approach and some of the more advanced function remained.

Some of the most important functions that remained, if compared to the initial list of functions, are:

- enable cursor control
- enable primary and secondary click
- enable page scrolling
- provide double-click function
- allow hands to operate in a centered position
- provide high system potential and customization of input actions

Also in the list were some functions that aimed at optimizing the dimensions and ease of use of the device. The complete revised list of functions can be found in Appendix 5.

8. Partial Solutions

This chapter explains all the different partial solutions that were developed from the function definition. Different areas are treated and the solutions for each area are presented. The chapter results in a morphological matrix that is used to find concept ideas in the next chapter.

8.1 SOLUTIONS FOR EACH PROBLEM AREA

Based on the revised list of functions five major areas were identified, to which ideas for solutions were to be found. The ideation process was performed through brainstorming with the aid of cards on which solutions could be sketched out and added to a pile of ideas.

The five areas were:
- **scrolling**
- **movement of the cursor**
- **clicking, including double-click function**
- **form and shape**
- **customizability**

After several ideas for each area were found, a first screening took place and some ideas were discarded. Others required some more processing and were discarded at a second screening. The rest of the ideas were gathered and summarized in a morphological matrix.

8.1.1 Ideas for scrolling

The following ideas for a way of scrolling remained after the first screening:

1. A touch sensitive strip to slide the finger along.

2. A scrollable rubber surface that moves and rolls with the finger tip.

3. A scroll integrated in the roll bar, activated by pressing a separate button.

4. A scroll integrated in the roll bar, activated by a touch sensitive surface in the roll that senses how many fingers are touching it.

5. An area on one side of the roll bar that is acting as a scroll wheel

Idea number 4 was discarded after the second screening due to an advanced technological solution. The fact that many users prefer to control the cursor with multiple fingers, and might consequently be confused from being forced to use only one finger for normal cursor control, is another reason for discarding the idea.

Idea number 5 was discarded because it may be difficult for the user to understand and know about this function. During the analysis of the MouseTrapper, that has a similar way of scrolling, this function proved to be hard to understand.

8.1.2 Ideas for movement of the cursor

The following ideas for the cursor movement remained after the first screening:

1. More then two degrees of freedom added to the roll bar. For example being able to push it forward and backward.

2. Arms holding the roll bar. Eliminates the need of an axle.

3. An ability to squeeze the roll bar to pick up and move objects.

4. A small ball that can be moved around a flat surface, but also lifted and rotated. Enabling many degrees of freedom and thus a big range of input actions.

5. A flat pad that moves with the finger tip, reducing the amount of friction.

6. A track ball. Can be rotated 360 degrees in all directions. Eliminates the problem of a roll bar hitting one of the ends.

All ideas except number 2 were discarded at this stage. Number 1 and 3 risked being un-ergonomic due to small precision actions in the fingers, and also technological challenges and barriers. The ideas could also end up being difficult to handle due to usability issues.

The ball, number 4, was discarded because it might end up un-ergonomic as well, due to small precision motions. Also it has restrictions when the ball reaches an end point and has to be reset somehow.

The pad that follows the fingers, number 5, will suffer from the same restrictions as a ball, decreasing the degrees of freedom compared to the current roll bar.

After this screening it was decided to keep the principle with a roll bar in the final design. The manufacturing process is well developed with high precision for the current roll bar, and also the recognition of the product is facilitated if the wide roll is kept.

8.1.3 Ideas for clicking functions

The following ideas for clicking functions, including double-click function, remained after the first screening:

1. Clickable roll bar, detecting which side is clicked and thereby whether left or right click should be performed.

2. A board that can be slid out from the Trackbar enabling use of more extra buttons and functions.

3. An exchangeable button pad for extra functions.

Double-click:

4. Click a surface and slide the finger slightly to activate double-click.

5. Touch-sensitive surface detects the number of fingers clicking it and thereby recognizes a double-click.

6. A two-step button. First step is single-click and by pushing a little bit harder, the second step is activated and a double-click action is performed.

7. Double-click by holding a regular button pressed down for a short time.

Idea number 4 was discarded due to possible usability issues and difficulties for the user to know how the function works.

8.1.4 Ideas for form and shape

The following ideas for form and shape remained after the first screening:

1. A support that can be folded out and raise the keyboard to better fit the height of the Trackbar.

2. A shape that enables the Trackbar to be turned around and put on top of a laptop, to reduce the distance to the keyboard.

3. A raised roll bar, to be positioned over the edge of a keyboard and thereby reducing the distance.

4. Ends of the Trackbar that can be folded out to adjust and resize the support for the hands.

5. The roll bar and buttons are covered with a shell that is slid open when it is to be used.

6. An opening under the roll bar to make dust automatically fall out and thereby enabling the Trackbar to clean itself.

7. A roll that is hanging more freely than the existing one. Makes it more accessible.

8. A roll bar that lies absolutely free on top of the Trackbar, making the Trackbar low and the roll easy to clean.

9. The buttons positioned behind the roll bar instead of in front of it. Reduces the stress for the thumbs.

10. A roll bar that can be raised and lowered, hanging on arms, enabling an adjustable height according to the keyboard.

11. A soft base, like a cushion, making it possible to position the Trackbar against laptop edges and thus coming closer to the keyboard.

Idea number 11 was discarded because it makes the Trackbar too high, which should be avoided. Idea number 10 was discarded because there is a technological difficulty in solving the optical readers and a clickable roll.

8.1.5 Ideas for Customizability

The following ideas for ways of customizing the functions of the Trackbar remained after the first screening:

1. An active surface that senses where the hand or fingers are held and according to their positions changes the function of roll bar. For instance making it a scroll wheel, or deactivating it when typing on a keyboard.

2. Buttons with displays to show which function is currently selected for the specific button.

3. Possibility to download firmware which can be used to reprogram the functions.

Changing the sensitivity of the roll bar:

4. Press and hold a button to activate a precision mode of the roll bar.

5. Use of a wheel to gradually adjust the sensitivity.

6. A touch sensitive strip to slide the finger along.

7. A manual slider, showing with its position which sensitivity is set.

8. A knob that can be twisted to adjust the sensitivity.

9. A traditional on/off-switch for precision mode.

Idea number 1, the active surface, was discarded because it was too advanced for this approach and since it could lead to issues in the usability.

Idea 2, buttons with displays, was discarded due to complex and expensive technology.

Idea 3 was not discarded, but removed from this phase, because it is applicable regardless of solutions.

Ideas number 5 and 6 were discarded in favor of the knob and the slider, because of higher usability demands on the user.

8.2 MORPHOLOGICAL MATRIX

The ideas that remained after the second screening was arranged and sorted into a morphological matrix. To make it clearer and easier to deal with, the categories needed some alterations. Some areas could be divided into more areas, because it was clear that there existed sub-categories within them.

Customizability was changed to *Change sensitivity*, since all the ideas that remained solved that specific problem.

Form and shape was divided into several categories: *design of the roll bar, how to fit the Trackbar to a keyboard, general shape of the exterior of the Trackbar* and finally *how the buttons would be placed*.

The morphological matrix is presented below. It was used to find ideas for concepts, which are presented in the following chapter.

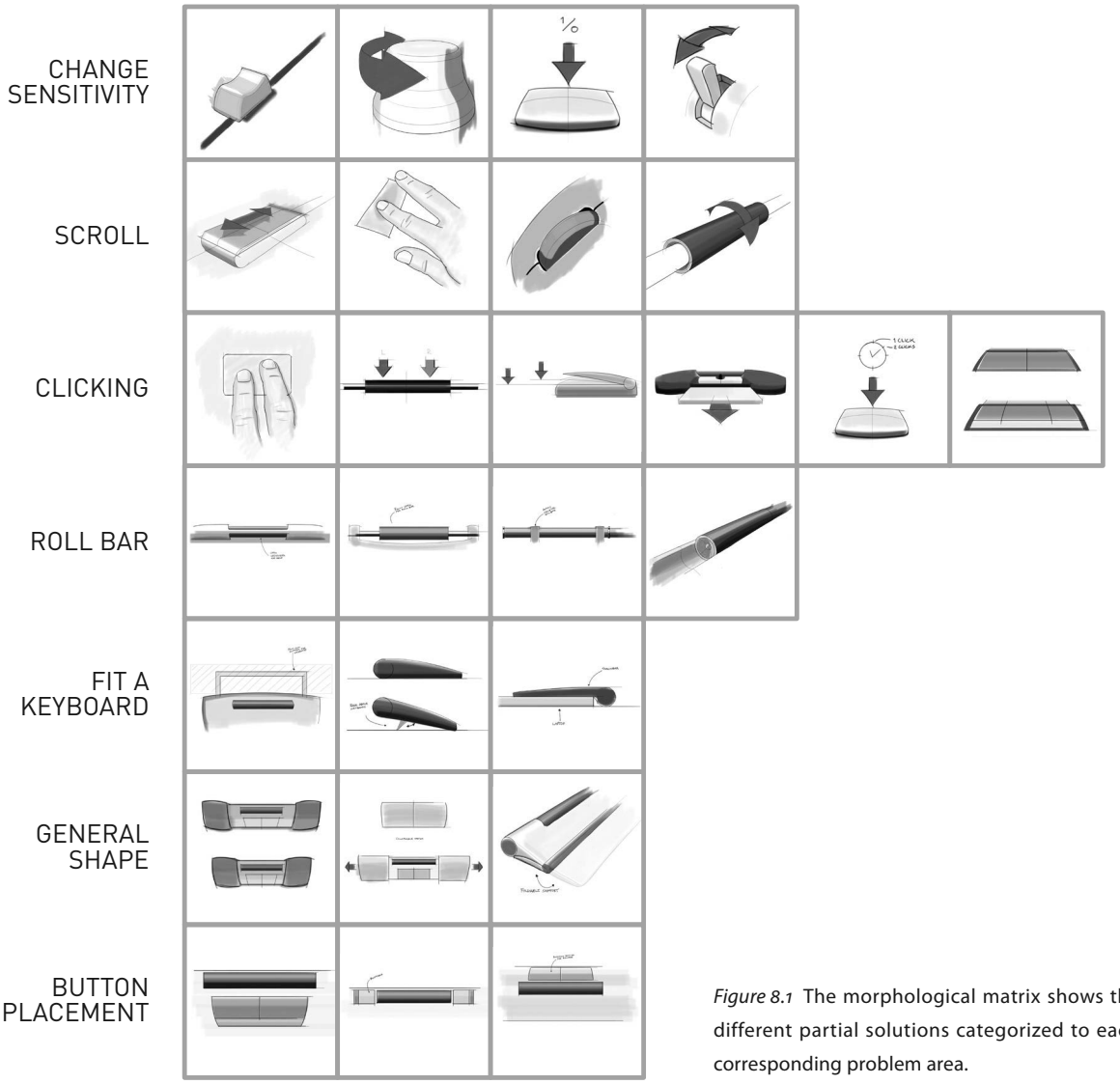


Figure 8.1 The morphological matrix shows the different partial solutions categorized to each corresponding problem area.

9. Concept Development

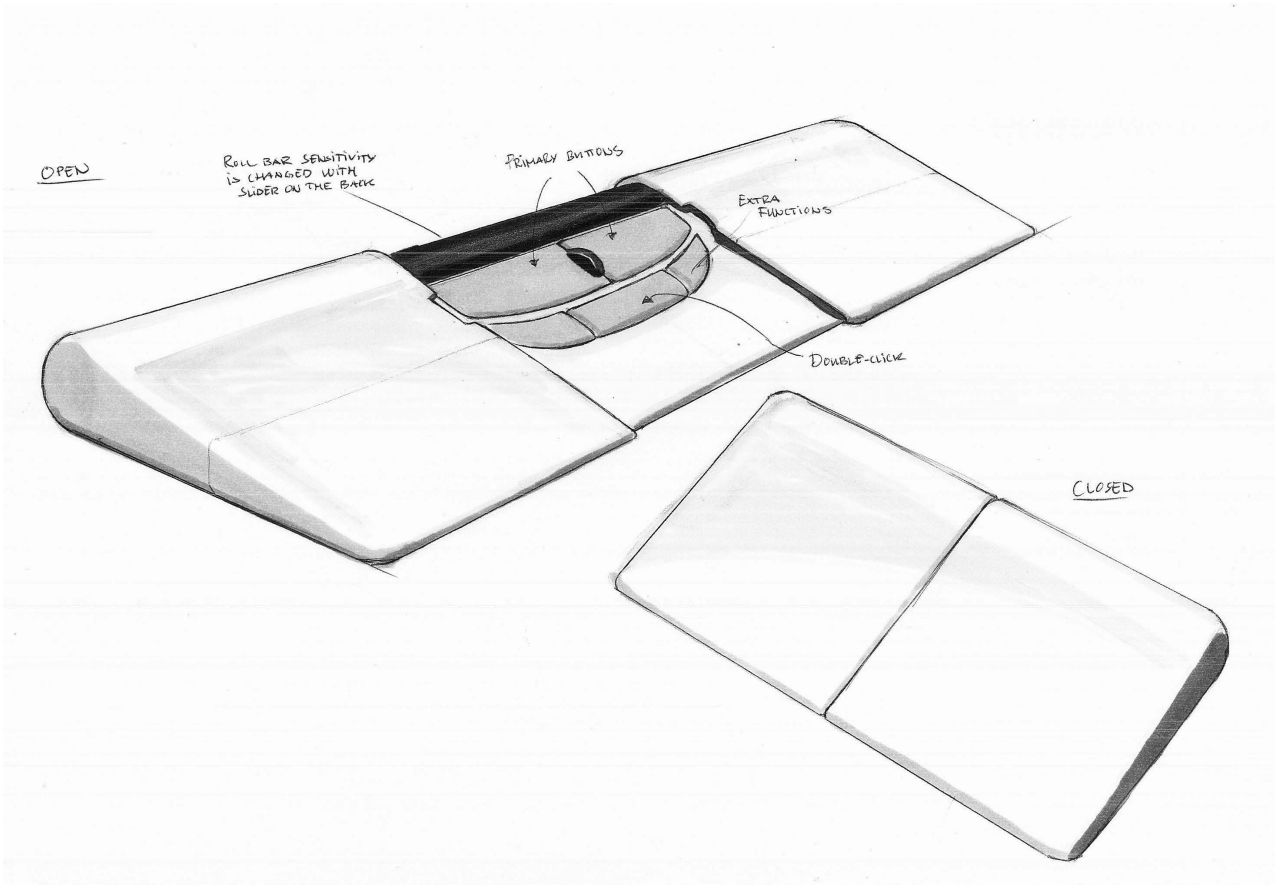
This chapter describes how five different concepts were developed based on the morphological matrix from the previous chapter. The benefits of each concept are explained, as well as why certain solutions were chosen. Sketches and photos of models are shown to further explain the concepts.

Together with image boards of various existing input devices the morphological matrix served as inspiration and guidance for the proceeding idea generation. An extensive sketching session resulted in several separate ideas for pointing devices based on the partial solutions in the matrix. Some ideas were complete but conceptual and others were just parts of a solution.

The sketches were organized according to which focus they had and grouped accordingly. The grouping was made in a KJ-analytical way, only with sketches instead of the regular phrases or words, and showed that there were five distinct concepts, that could be connected back to the matrix. Some concepts were missing solutions for certain functions, but they could be found using the solutions in the matrix.

Once all functions of the five concepts were chosen they were defined by making sketches, life-size mock-ups and a drawing of the button layout. This representation was made in order to evaluate ideas with users and ergonomists.

For all the following concepts the reader should keep in mind that programmable buttons increase the potential with the concepts by letting the user download or install a software that enables individual customization.

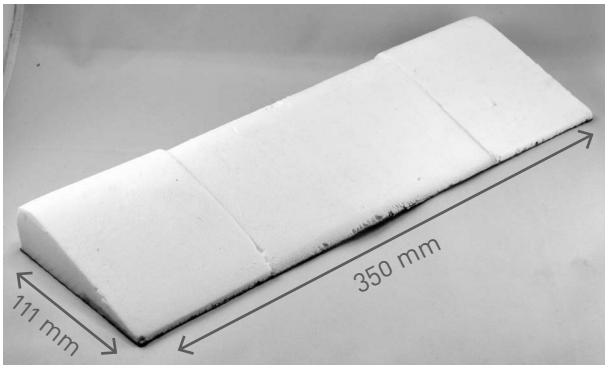


9.1 SLIDER

This concept benefits from its shell, that can be opened and closed around the roll bar and buttons. The top casing is slid apart to the sides to reveal the controls. The design enables a portable size and at the same time can provide a wide design for arm support when typing on a keyboard. The case also protects the sensitive roll bar and scroll wheel during transportation.

The buttons are regular clickable switches, like the current Trackbar model, where the primary ones are large to be easily recognized as the most important buttons. There are two buttons for extra functions, and one in the middle with a double-click function.

The sensitivity of the roll bar can be changed with a slider on the backside of the bar.



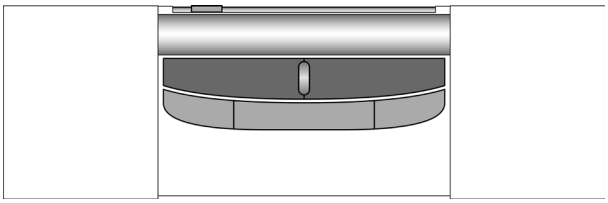
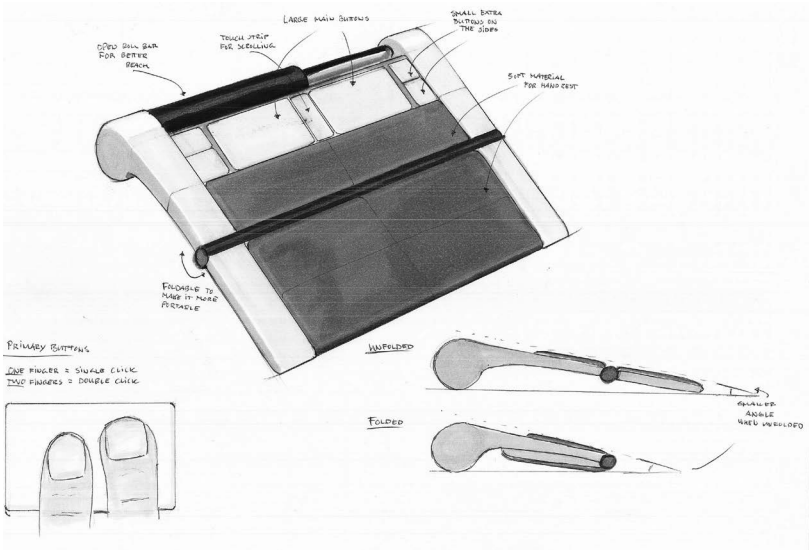
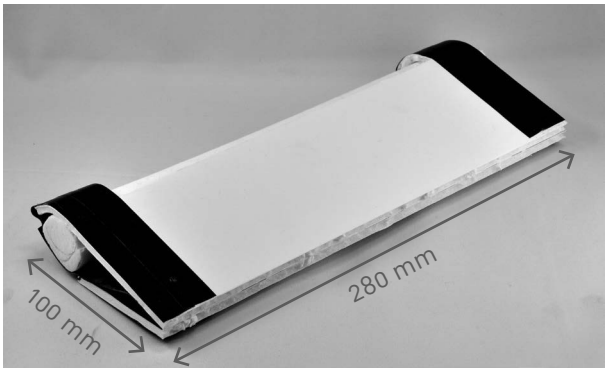
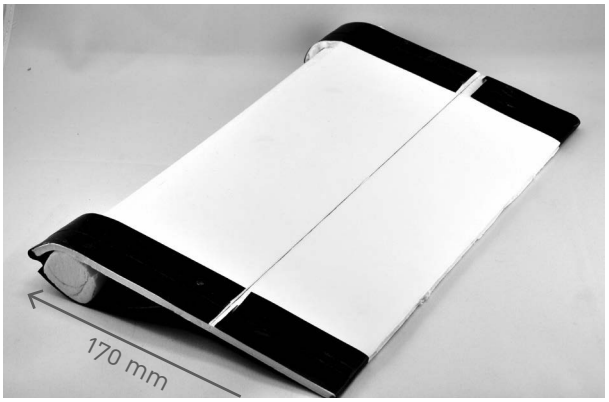


Figure 9.1 The Slider concept presented in three ways; sketches, a mock-up model and a button layout.







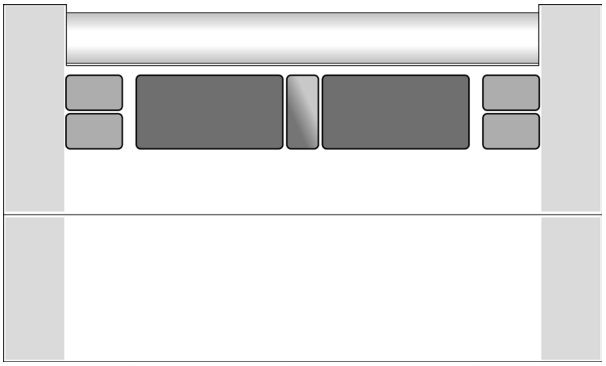


Figure 9.2 The Folder presented with sketches, a mock-up model and a button layout.

9.2 FOLDER

The *Folder* has a straight shape in a slight angle from the table top surface to the keyboard height and a large flat surface as support. The surface is covered with a padded soft material for optimal comfort. The construction can be folded close to the horizontal center line and part of the support area can be hid under the device. This gives an adjustable size and angle of the device. Making the device smaller by folding it is also beneficial during transportation.

The thin flat support area makes it possible to turn the whole device 180 degrees around and place it on top of a laptop, in front of the keyboard. It reduces the distance between the user and the keyboard for a minimal reach. It also reduces the distance between the buttons on the device and the keys of the keyboard, giving the hands a shorter distance to travel while switching between typing and mousing.

The buttons are touch sensitive to make them flat and reduce the required click force. The primary buttons are large and are accompanied with four smaller buttons for extra functions.

The main buttons can sense whether one or two fingers are used and consequently be used for both single- and double-click actions.

Between the primary buttons is a touch sensitive strip used for scrolling.

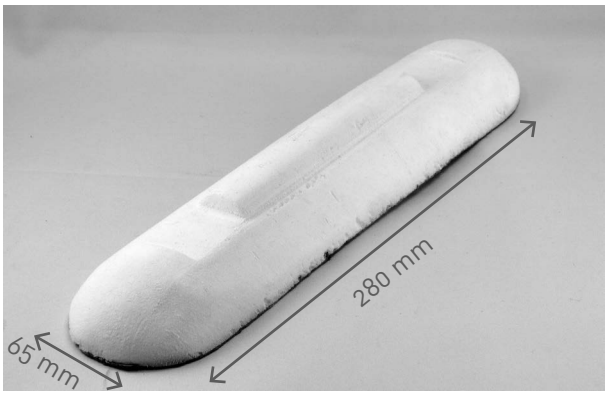
The roll bar has an open design to make it accessible and easy to reach.

9.3 CYLINDER

This concept is held on a simplistic level trying to minimize the functions. All the interaction is in the roll bar itself, and the rest of the device is kept at a minimum. It has a thin design which reduces the depth of the device and thus also the reaching to the keyboard. The size makes the *Cylinder* a very portable concept.

The roll bar is clickable; one click performs a single-click action and clicking and holding it shortly will perform a double click action. The roll can also sense on which side it is clicked by having a tilt function built in. The user can choose to do a left- or right-click by clicking that side of the roll.

The two buttons on the side of the roll bar are used to activate the scroll function, which is integrated in the roll bar, by holding either of them down.



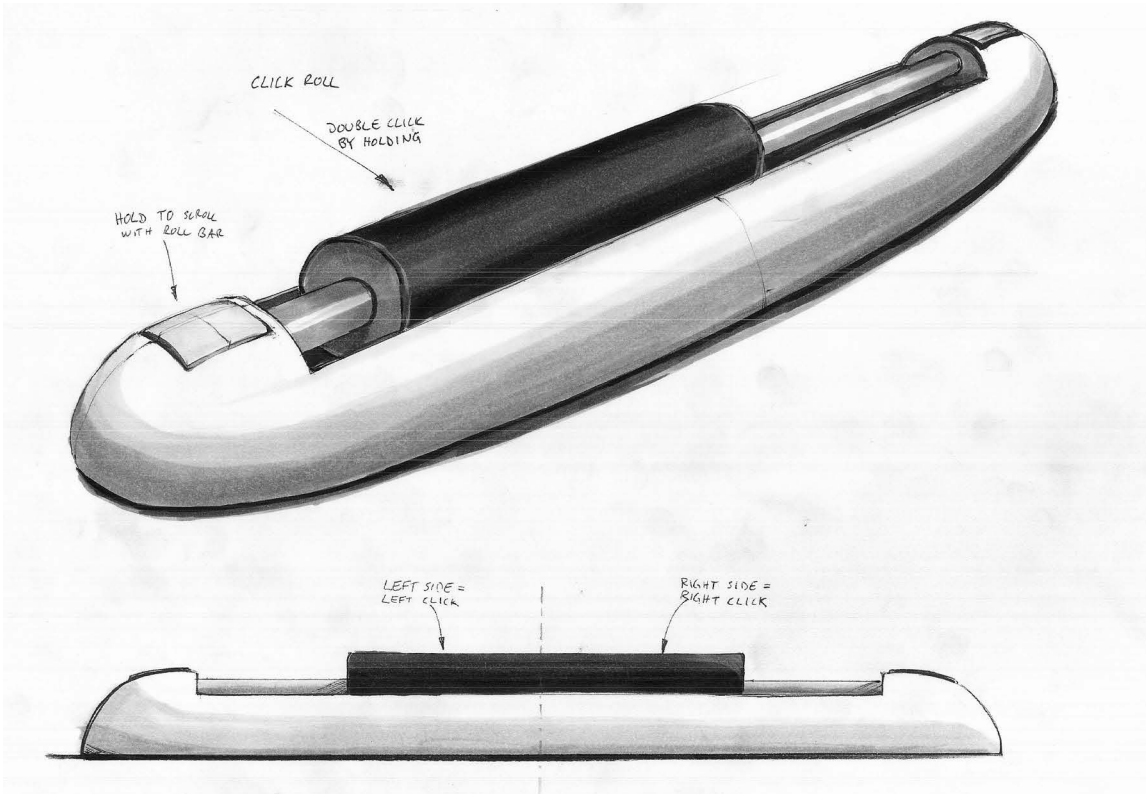
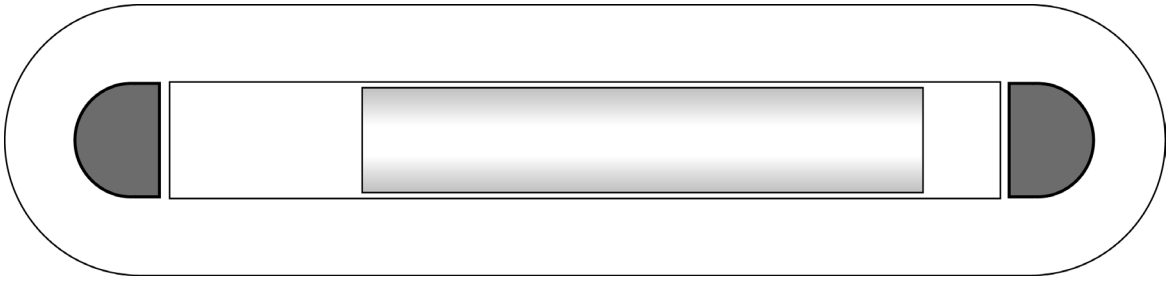


Figure 9.3 The Cylinder concept presented in three ways; sketches, a mock-up model and a button layout.

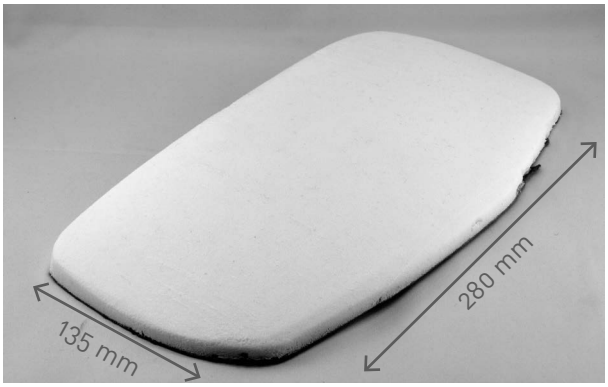


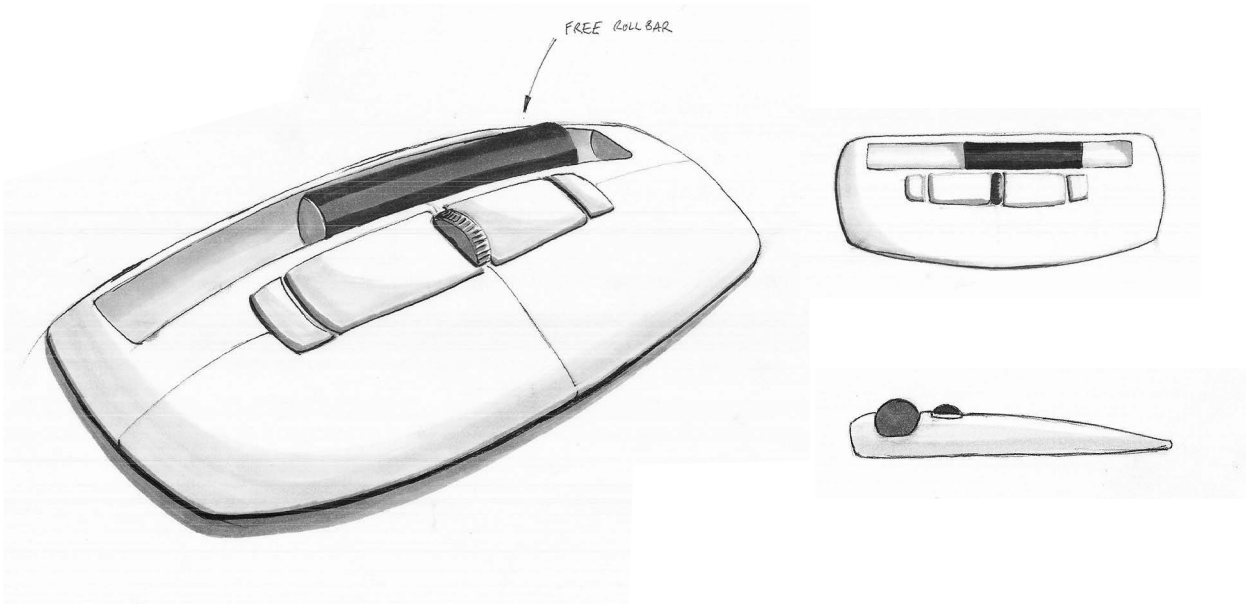
9.4 SLIM

The design is low and slim and has a slightly rounded surface to provide the user with a comfortable support. The roll bar lies freely in a trench on the top, which gives an easy way of cleaning the it. Since there is no need for an axle the design allows the profile to be thin all the way to the sides.

There are two large primary buttons and two smaller extra buttons for back/forward or other specific functions, like double-click.

The scroll wheel has a conventional design, which is easy to understand for most users thanks to a high level of recognition.





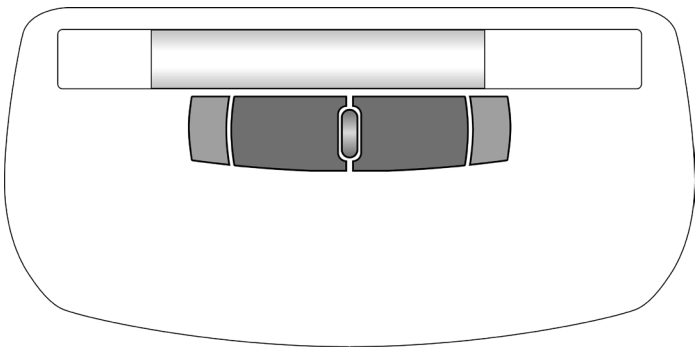


Figure 9.4 The Slim concept presented in three ways; sketches, a mock-up model and a button layout.

9.5 ANGLED

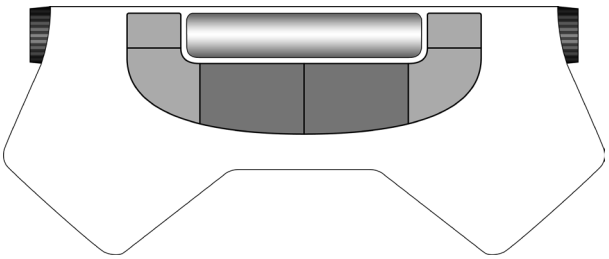
This design is made with two prominent arm rests to have an angle that is near the angle that the arms and hands approach the device. It can help the user to understand the ergonomic benefits of the product since the supports communicate that they should be used as arm rests, and that both hands can be used.

The buttons are aligned around the roll bar for easy reach whilst operating the it, and the primary buttons are larger than the others. There are four programmable buttons available for extra functions.

On each side of the roll bar, at the very ends, are two knobs. As a default the knobs can be used as scroll wheels, and by having two, the flexibility is increased for the user.

The knobs will also increase the potential of having more advanced functions, since they can be programmed to the user's preference. They can be programmed individually and give the user the ability to adjust a great variety of functions. Some things that the knobs could be used for are:

- **adjust the volume**
- **skipping tracks in video or audio software**
- **fast or slow playback in video software**
- **adjusting opacity/color/saturation etc in a photo editing software**
- **change the sensitivity of the roll bar**
- **a drop down menu for selecting tools**
- **zoom and pan**



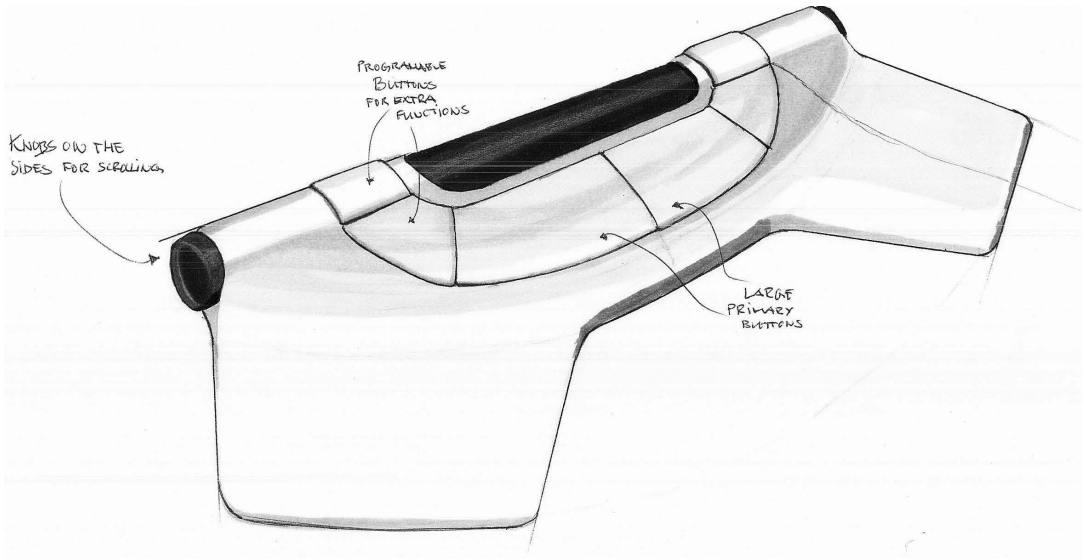


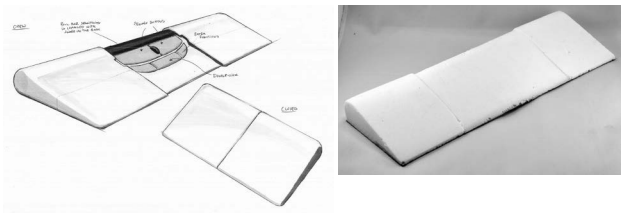
Figure 9.5 The Angled concept presented in three ways; sketches, a mock-up model and a button layout.

10. Concept Evaluation

This chapter presents the results of the concept evaluations from the Ergonomics Roundtable of Sacramento and the focus group held with the long term test participants at Stanford. The chapter results in two lists of pros and cons; one for the concepts and one for the different partial solutions.

10.1 EVALUATION WITH USERS

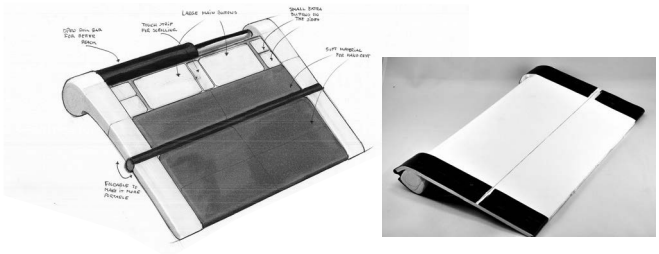
The comments from evaluating the concepts with the long term test participants are summarized below.



10.1.1 Slider

The participants liked that the design was closable and thought that it was a smart idea. However, they stressed that it has to be very robust in order to resist wear from being opened and closed many times a day. They liked the convenient size when the device is closed, however the design was still considered to be too high.

The slider for changing the sensitivity was considered to be good. And the idea of using it for other functions such as changing colors in graphic design software for the more advanced user came up.



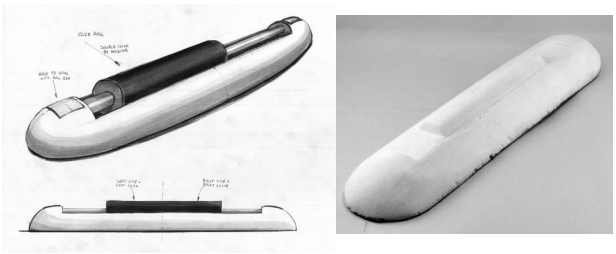
10.1.2 Folder

The users did not see the point of having a folding design right away. When it is unfolded and used with a laptop the distance to the keyboard is too big, specifically for small persons. And turning it around would still give a distance between the keys and the roll bar. However they liked the idea once the benefits of the design where further explained.

The concept was considered to have too many buttons and too many different input methods: a mechanical roll bar, buttons and a touch strip for scrolling. This was confusing for the participants in the focus group. They like to feel the movement when scrolling and therefore disliked the touch strip due to the lack of tactile feedback.

The idea of having many functions implemented in one button was not liked by everyone. One user said that it is very irritating with buttons that do many things, and at the same time another user really liked her trackpad with finger gesture functions.

Further, the users thought that the device was too high for their laptops.

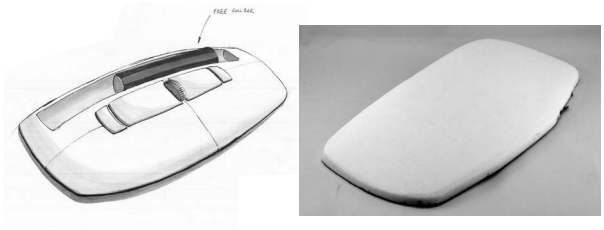


10.1.3 Cylinder

The idea of having a simple, striped down version was liked, as well as the integrated functions in the roll bar. But they did not like the idea of having to customize the functions themselves, meaning the default functions have to be very good.

The design gives no support when typing on the keyboard, the roll bar and the buttons would be in the way and users would probably press them by accident while typing. The roll bar itself needs to be, or could be much narrower, in order for the arms to fit around it.

One user had a wide, soft jelly cushion as an armrest and she said that she would have liked to have a pointer in that.

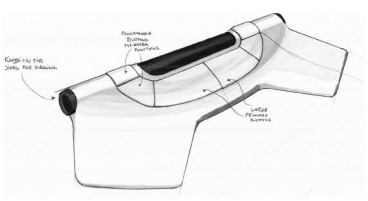


10.1.4 Slim

The height and shape of this concept was appreciated, even though it could be even flatter. They liked how it supported the hands and thought that it was comfortable. Otherwise the concept was thought to be too big,

specially the depth, which would add to the distance from the keyboard.

10.1.5 Angled



The knobs on each side of the roll bar where liked by the focus group, since they like to be able to use either hand. One user exclaimed that "for me that would be perfect. But you know what? I don't want to deal with it. I just want that damn thing to work!" Once again stressing the importance of good default functions. "Things like this they work or they don't and if they don't you get absolutely pissed off!"

One person also said that advanced functions require education of use.

10.2 EVALUATION AT THE ERGONOMICS ROUNDTABLE, SACRAMENTO

Apart from the five concepts some general feedback and some feedback regarding Trackbar Emotion was provided.

10.2.1 Trackbar Emotion

Some of the ergonomists had used an older version of Trackbar and one of them thought that the new rubberized roll bar was much worse than the old silver-style, because lint gets stuck on the surface.

Huge, overweight, people or other users with extremely wide shoulders have a hard time using Trackbar because they are too wide to reach in with their hands.

10.2.2 General feedback

The steep angle of some of the concepts lead to an extension of the wrist, which may lead to stressed tendons and ultimately CTS.

One person would prefer the roll bar to be in a very bright color to increase the contrasts in order to see the roll bar in the peripheral vision.

Many people commented on that there are no centered pointing device made to fit ergonomic keyboards. That increases the reaching, because the CPD can't come close enough to the keyboard.

One ergonomist insisted that supports are not good because it tends to lock the positions of the hands, resulting in the person only moving the wrist instead of the shoulder. "Pause the hands there, don't plant them."

10.2.3Slider

They liked the design because it makes it possible for the mouse to be rather wide which makes it fit more users.

10.2.4 Folder

There should be an option to remove the inclination completely so that the mouse has a zero degree angle. This could make it fit the ANSI standards, which might have a good marketing value. The ANSI (American National Standards Institute) standards for the angle may be 0-15°. They call it the "angle of attack".

It would be good to increase the length of the roll bar for larger users.

10.2.5 Cylinder

It is good with an exposed roll bar since it automatically increases the length, making it reachable from different postures.

10.2.6 Slim

The shape communicates how it should be approached and it supports the correct areas of the palm. The soft cushioned parts of the palms are where the support should be placed, not thinner areas of skin where blood vessels, bone structure and tendons are right beneath the skin surface. This makes it very usable for mouse intensive work, because the user can stay on the mouse. However, the design is too deep to use with a keyboard since it forces the user to reach too far.

10.2.7 Angled

The position of the knobs on the sides could result in ulnar deviation, which should be avoided. Also it may lead to the user operationg them with the little fingers, which should be avoided.

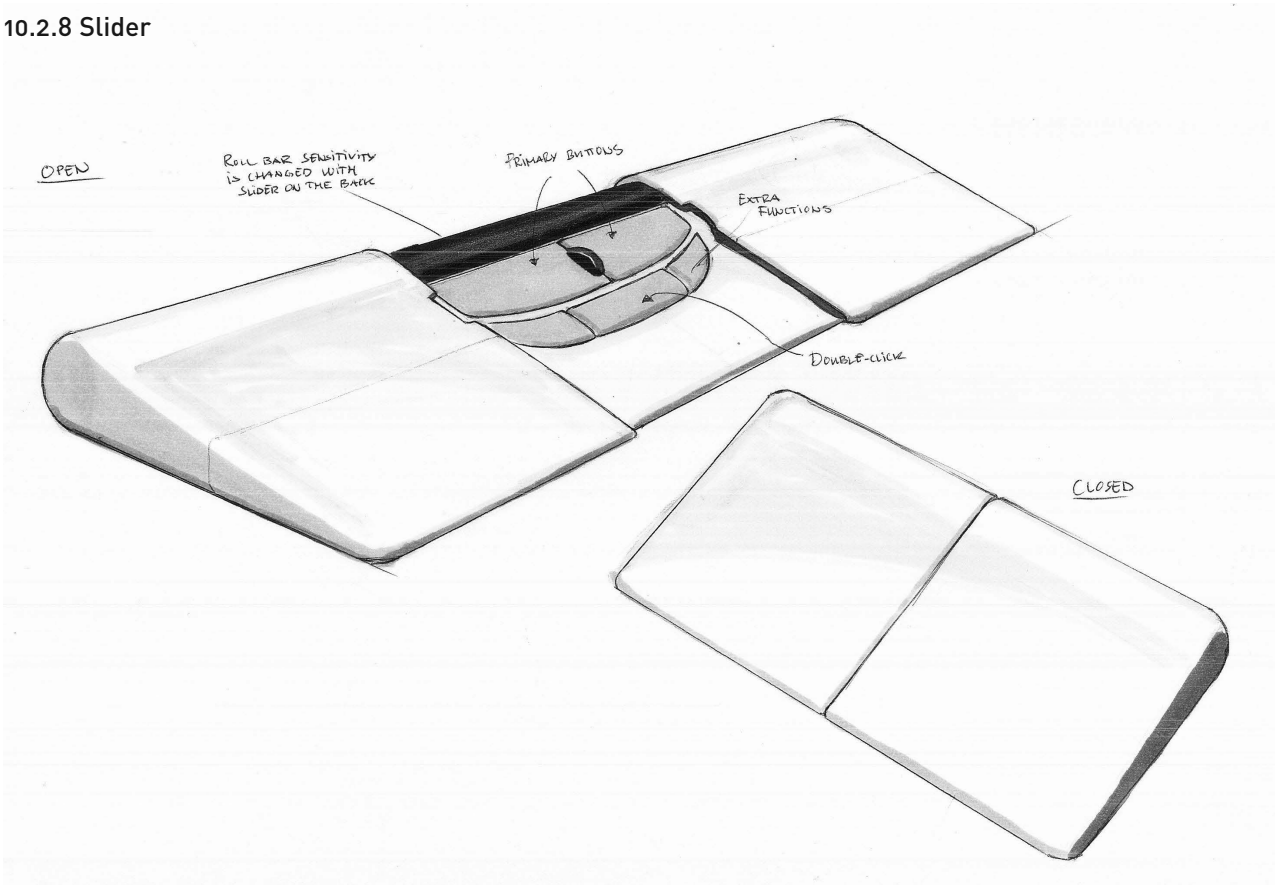
The shape makes it possible to position the CPD close to the body and thereby minimize the distance to the keyboard. Furthermore, it would be good if it could have the same curve as an ergonomic keyboard.

This design could fit work where the positions of the hands vary between the keyboard and the mouse.

10.3 PROS AND CONS

All the concepts were analyzed with the external feedback as a base and a list of pros and cons was created to summarize the evaluation.

10.2.8 Slider



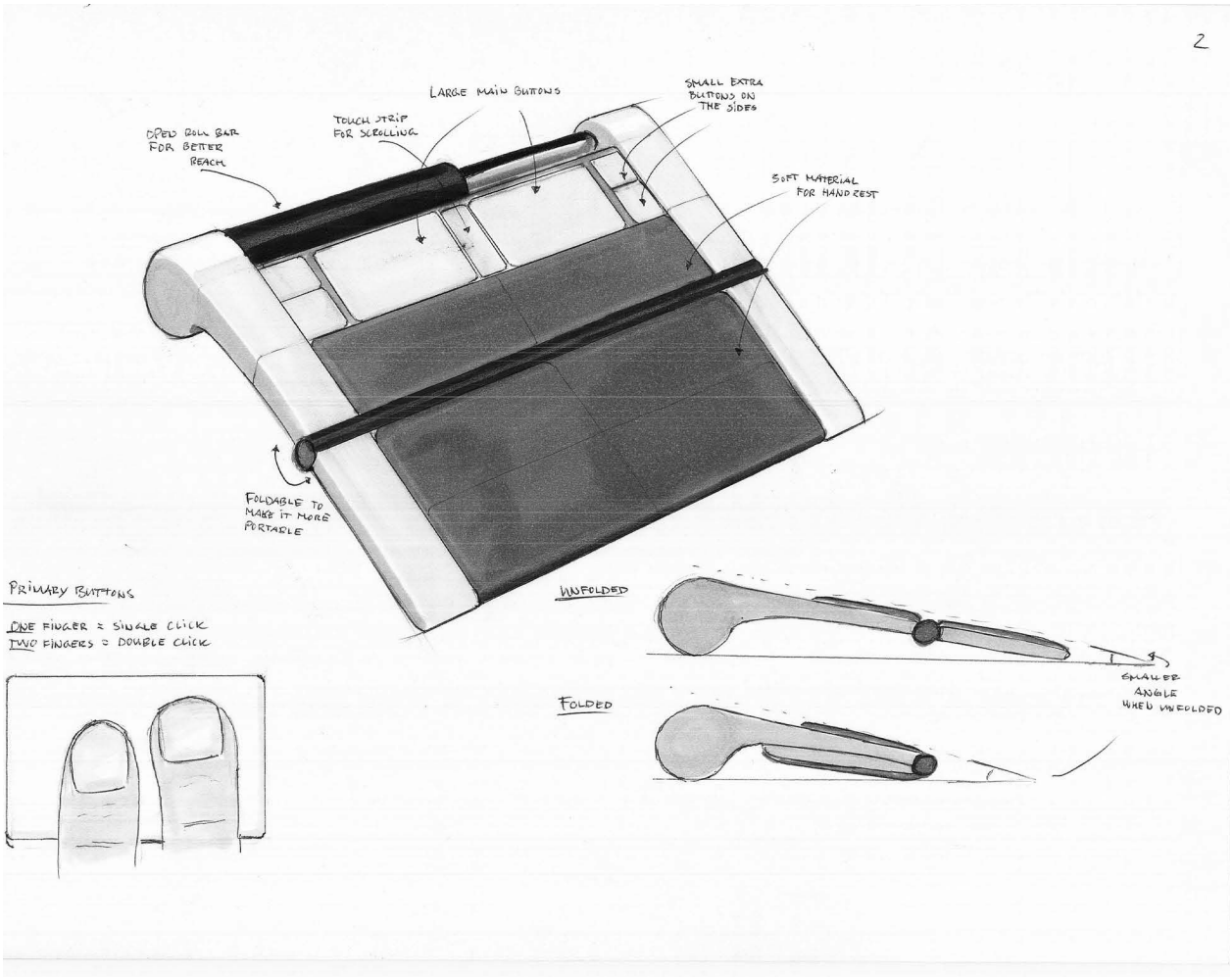
Pros

- Due to the closing function the concept is portable.
- When open, the concept is wide and provides a good support for users with different shoulder width.
- The slider for changing the sensitivity has a great potential.

Cons

- Because of the moving parts, the concept may be subject to wear and tear.
- The concept would have to be made out of many different parts, this would lead to higher production costs.
- The position of the slider would add to the depth of the concept, specially the distance from the roll bar to the keyboard.

10.3.1 Folder



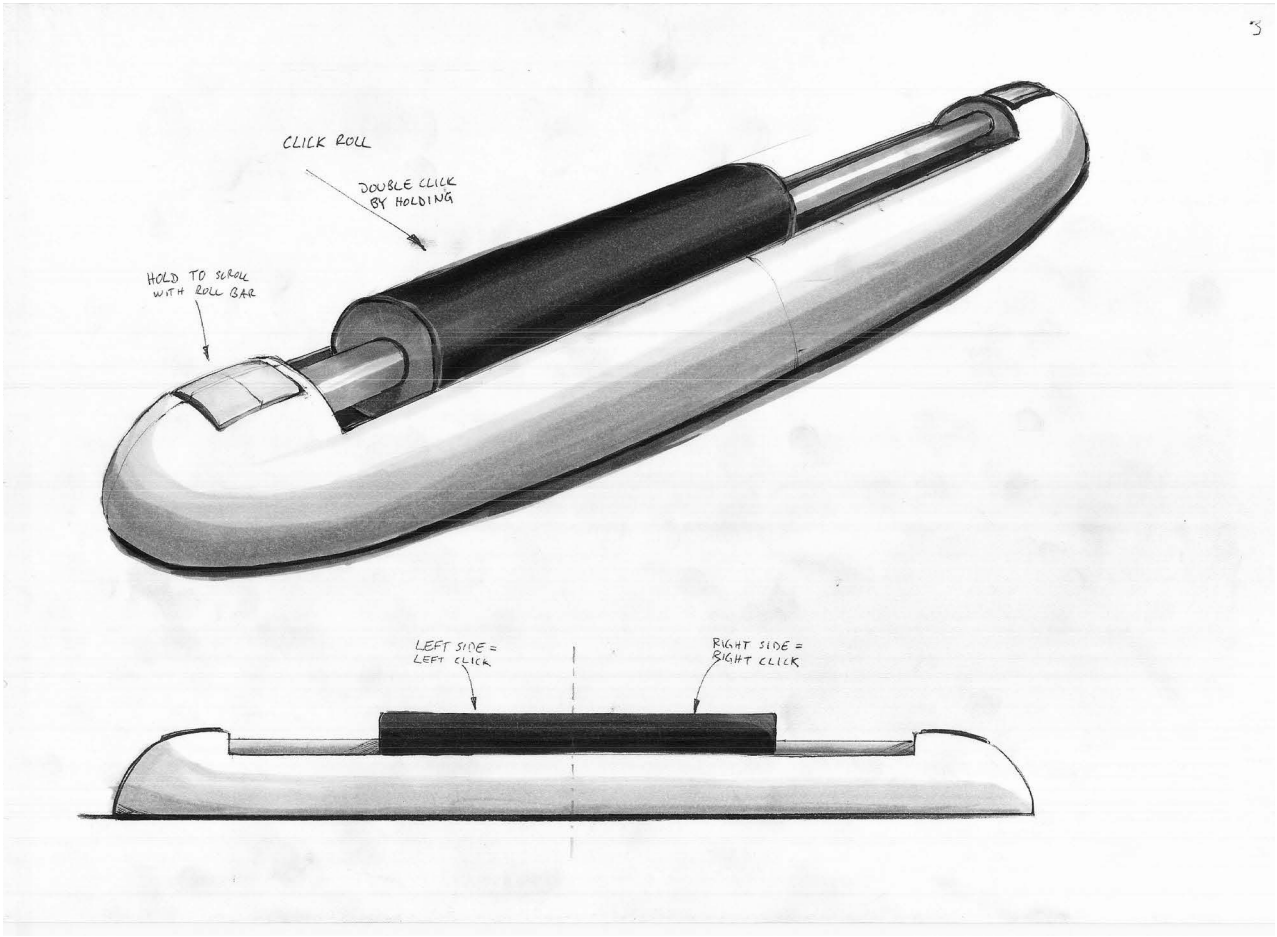
Pros

- The concept provides high flexibility. It can be turned around or folded to turn in to a portable product.
- When the concept is unfolded it provides a big support and a small angle for the forearms.
- The concept provides a big area of access to the roll bar.
- It can be placed on top of a laptop and that way bring the hands closer to the keyboard.

Cons

- The touch strip was not liked by the focus group. It is a different input method and together with the other inputs it may be confusing.
- The concept has moving parts and therefore it is subject to wear and tear.
- The depth of the concept is big.
- The concept would have to be made out of many different parts which would lead to higher production costs.

10.3.2Cylinder



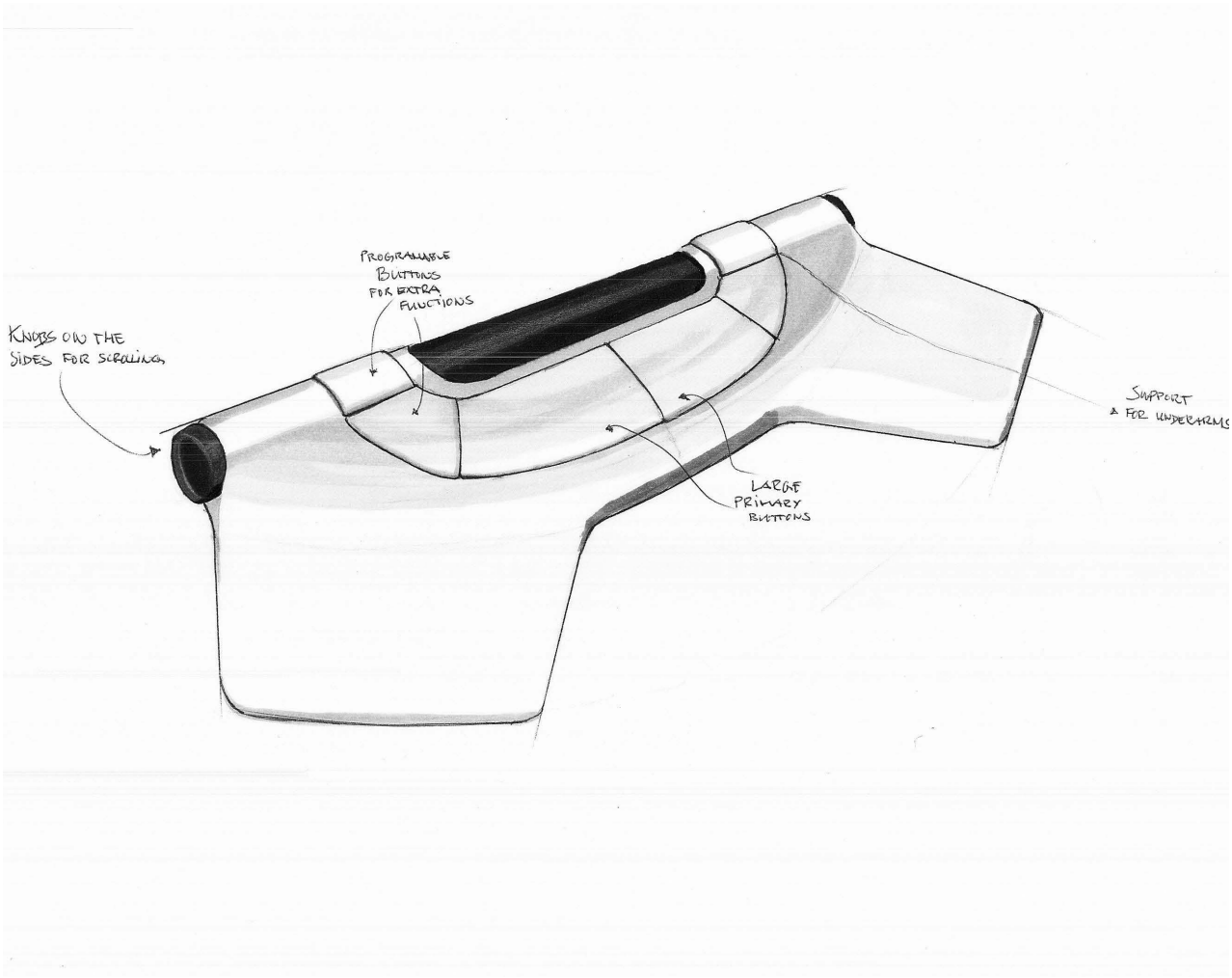
Pros

- Due to its size, the concept is very portable.
- The roll bar is easy to reach all over the product.
- The integrated functions in the roll bar give a high potential of use.

Cons

- Doesn't provide support while typing on a keyboard, would rather be in the way so that buttons might accidentally be pressed.
- The multiple functions in the roll bar could be hard to understand.

10.3.3Angled



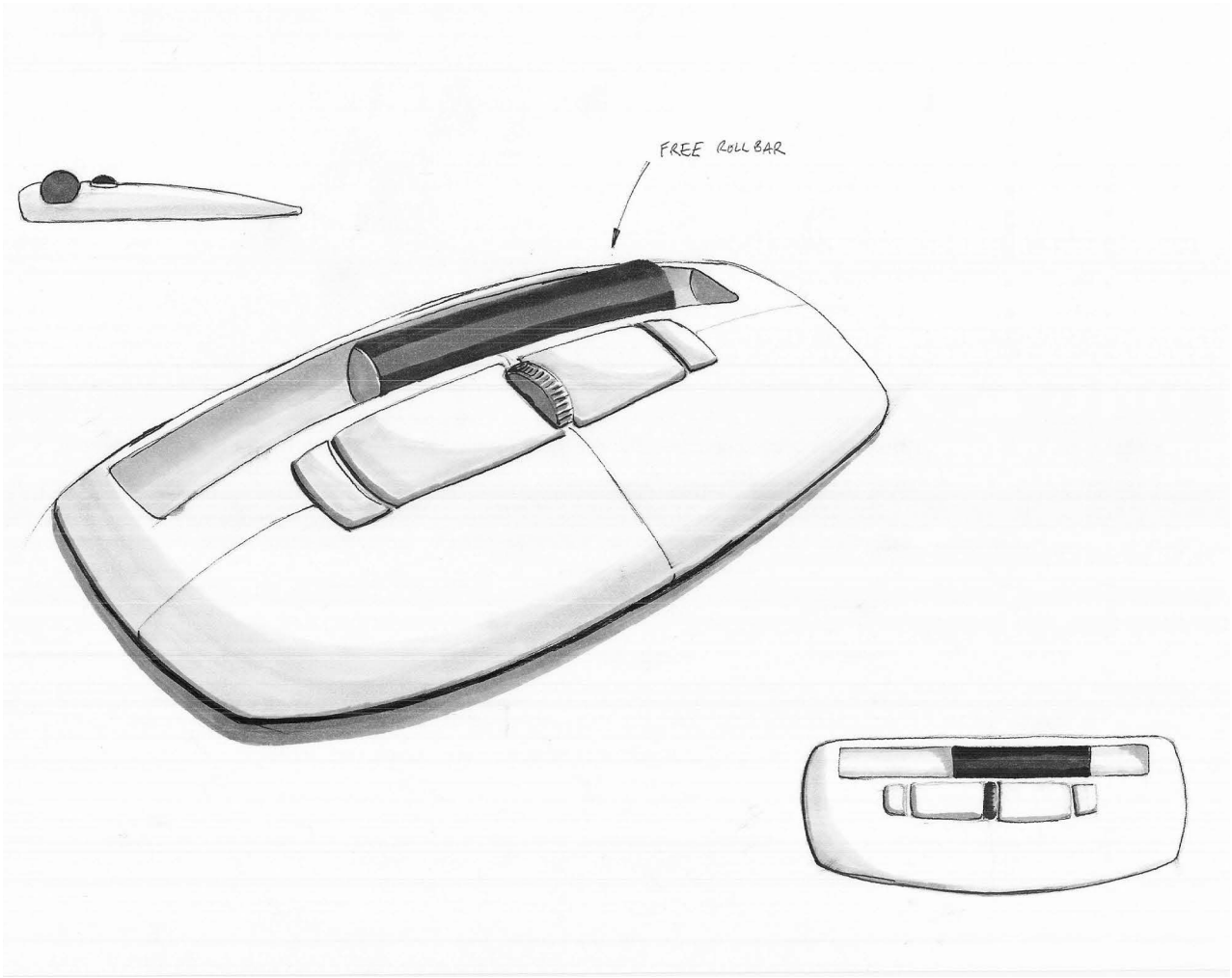
Pros

- The concept is shaped so that it could come closer to the body and at the same time provide support.
- The knobs on the sides give a high input potential.

Cons

- The position of the knobs may cause ulnar deviation in the wrist.
- The buttons on top may be in the way while typing on a keyboard.
- The max depth is big which makes it less portable.

10.3.4 Slim



Pros

- The shape provides good and comfortable support at the right place for the hands while performing mouse intensive work.
- The open design makes the roll bar very accessible.
- The open design makes it easy to clean.

Cons

- The concept has a large depth leading to more reaching.
- The roll bar might be in the way while typing on a keyboard.
- The roll bar needs to be locked while the product is being transported.

10.4 EVALUATION OF THE PARTIAL SOLUTIONS

The pros and cons of the different partial solutions are presented below.

10.4.1 Roll bar

In the concepts there were three different ideas on how the roll bar could be designed; *Free roll bar*, *Open roll bar* and *Closed roll bar*.

Free roll bar - The free roll bar lies in a trench without an axle, as in the Slim concept.

Pros

- Using a trench makes it possible to have a slimmer shape of the device.
- The roll bar can easily be lifted out to enable cleaning.
- The user can see when the roll bar reaches the end, making the reset function more intuitive.

Cons

- Some new technical solutions have to be developed. E.g. how the rolling and clicking should work, and how to lock the roll bar during transportation.
- The roll bar might be in the way while typing.

Open roll bar with axle - The roll bar is fully accessible but there is still an axle on which it is mounted.

Pros

- May be possible to reduce the height somewhat.
- Uses the existing solution with an axle.
- The user can see when the roll bar reaches the end, making the reset function more intuitive.
- Easy to reach the whole width of the roll bar.

Cons

- Dirt might enter the construction
- The roll might be in the way while typing.

Semi Open roll bar

A way of solving how the roll bar might be in the way while typing could be to have a semi open roll bar. It has the same benefits as the open roll bar, except that the hands would have a little more support while typing. However the user can't see when the roll bar reaches the end and it wouldn't be possible to make it as low as the fully open roll bar.

Closed roll bar with axle - This is how the Trackbar works today, only the roll bar is visible and not the axle.

Pros

- Support on the sides while typing.
- Uses the existing solution with an axle.

Cons

- A small area to access the roll bar from.
- Increased height of the device.

10.4.2 Scrolling

Three different ways of scrolling were evaluated; using a regular *scroll wheel*, *the knobs* or *the roll bar*.

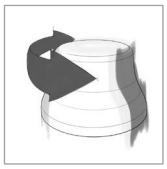
Scroll wheel - A regular scroll wheel is commonly used in computer mice today and the existing Trackbar has this solution.

Pros

- A regular scroll wheel is compatible with the user expectations and therefore easy to understand.

Cons

- Increases the height of the device, since it is a big component.



Knobs - Scroll wheels mounted on the outer ends of the device.

Pros

- Either hand can be used.
- High potential for the advanced user (the knobs could be used for other functions).
- Easy to understand.

Cons

- The position of the knobs may cause ulnar deviation in the wrist.

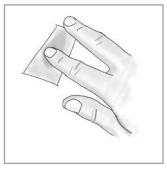
Scroll with the roll bar

Pros

- Uses the roll bar and no extra input is needed.
- Many users expressed a desire to have this function.

Cons

- Might be difficult to solve technically.



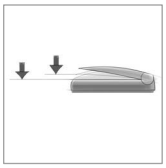
Touch sensitive strip

Cons

- Means many different types of input, which can be confusing.

10.4.3 Double-clicking

Three different ways of providing a double-click function were explored in the concepts; *Two-step button*, *Two finger click* and a *Dedicated double-click button*.



Two-step button - A button with two steps, where a light pressure produces a single-click and pressing harder produces a double-click.

Pros

- Only one button for primary single-click and double-click.
- Gives good feedback of what is going on.

Cons

- There is a risk of double-clicking by mistake.
- To perform the double-click a greater force is needed which might not be ergonomically ok.

Two finger click - A button that produces a single-click when pressed with one finger and a double-click when pressed with two.

Pros

- Only one button for primary single-click and double-click.

Cons

- A function that needs to be learned and might cause confusion.
- There is a risk of double-clicking by mistake.
- Some users may use two fingers to click buttons.

Dedicated double-click button - A button which is dedicated to a double-click function.

Pros

- Ergonomically tested and good.
- Easy to understand (other similar products have it).

Cons

- One extra button.

11. Concept Refinement

This chapter explains which parts from each of the concepts from chapter 10 that were kept for the next iteration of a concept, based on the evaluation together with both users and ergonomists. The chosen functions are presented, and is also explained why they were chosen. Finally the refined concept is presented.

11.1 FUNCTIONS TO KEEP

Chapter 10 shows how each concept has some strong and some weak elements. As it turned out after the different evaluations one specific concept wasn't considered the best one, but they all had some benefits. This led to the conclusion that the good elements from different concepts could perhaps be combined into one final concept. Below is an explanation of the different elements that were kept, followed by a presentation of the refined concept.

11.1.1 Shape and ability to fit a keyboard

The Folder concept had the best potential to adapt to and fit a keyboard. The idea of reversing it gives the user the opportunity to choose style according to the situation or preference. The folding feature was discarded but the thin main surface was kept thanks to its ability to fit a keyboard well.

11.1.2 Roll bar

The open roll bar with an axle was chosen thanks to the already well established manufacturing method and that it helps keeping the height of the Trackbar down. Most of all it makes the roll bar accessible and easy to reach. It also makes it easy to see or feel where the roll bar is located, so the user doesn't get surprised when it reaches the end point and resets.

11.1.3 Changing the sensitivity of the roll bar

To make the Trackbar easy to understand and use, the number of buttons and controls should be minimized. For most users changing the sensitivity of the roll bar might not be necessary, only for some more demanding users working with precision demanding software. Therefore a specific slider or similar was not incorporated, but a precision mode can be entered temporarily when holding a button pressed down. This function is consequently not very protrudent or obvious, in order not to make it interfere with a basic user. The more advanced user may however learn the feature quickly.

11.1.4 Scrolling

Many users, during the problem definition, requested the function of having the scroll integrated in the roll bar. They claimed it felt natural to have it there, since there is already a large roll bar, and it felt natural to scroll with it.

However, the knobs on the sides where kept for a final design because of the positive reactions from the users; they seem easy to understand thanks to their shape and they provide a very high potential.

11.1.5 Button placement

From the user evaluations it was clear that the buttons should be easy to understand and that there can't be too many. Still the device has to have a high potential for more demanding users. Therefore it was decided that the most important and most commonly used buttons should be kept in a position where they are easily recognized. Also the number of buttons should not be too high. There may however be more buttons or functions, as long as they don't interfere with the basic users.

11.1.6 Double-clicking

Due to the many possible usability issues and risks of mistakes with the two-step button and two-finger clicking, a single dedicated double-click button was chosen. It is ergonomically well tested, and will not require any special motions by the user.

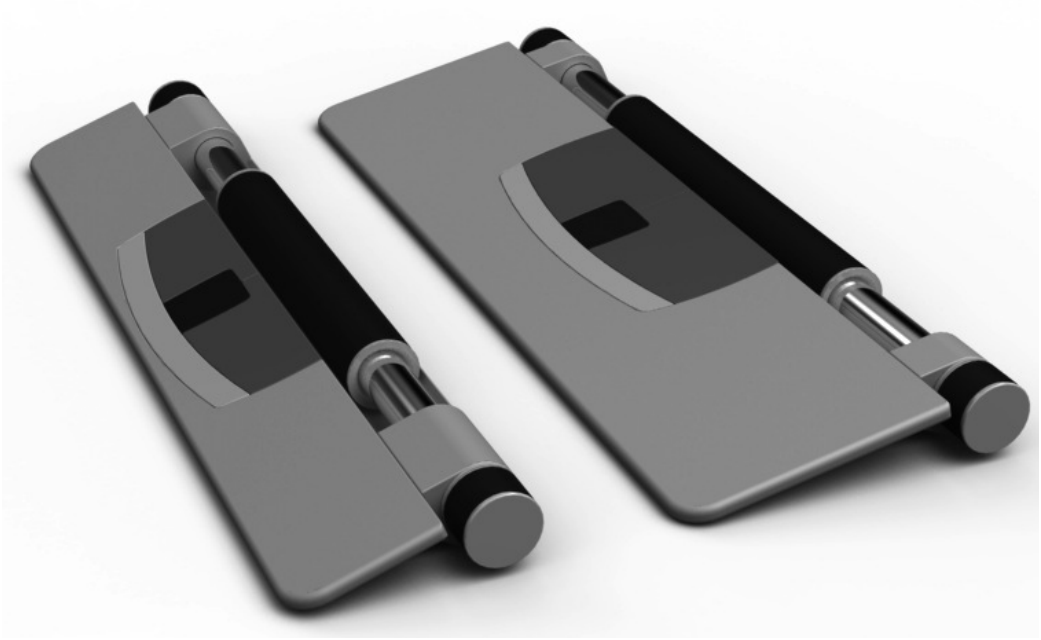


Figure 11.1 The refined concept was made in two sizes, 120 mm and 65 mm deep.

11.2 THE REFINED CONCEPT

By combining the best partial solutions from the five concepts above a new concept could be constructed. Keeping it on a conceptual level, not digging in too deep into details, the following design was found through some sketching sessions.

The roll bar was given the open design, visible in Figure 11.1, thanks to the benefits of a low profile, easy access and that the user can see when it reaches the end points, which prevents unexpected resetting of the cursor. This design could also make it easier to keep the roll bar and its housing clean.

On the backside of the roll bar, the side that is facing the keyboard, there is a small protruding ledge which gives the device a small distance to the keyboard (Fig. 11.2). This prevents the roll from hitting or getting stuck at any protruding parts of the adjacent keyboard.

One thing that was not clear during the evaluation was the depth of the device. Therefore the new concept was made in two different versions, one deeper - around 120 mm deep, and one less deep - around 65 mm (Fig. 11.1).

A few other differences were made on the two versions; the width of the *collars* (Fig. 11.3), carrying the housing for the axle and roll bar attachments. On the deeper version the collars are narrower, providing a long distance for the roll bar to travel, which gives larger freedom to move the cursor. On the smaller version, however, the collars were made wider, 30 instead of 15 mm, to provide a little bit more support for the wrist when typing. For this version the roll bar got a shorter distance to move, which gave birth to the idea of making it shorter; 120 mm instead of 140 mm.

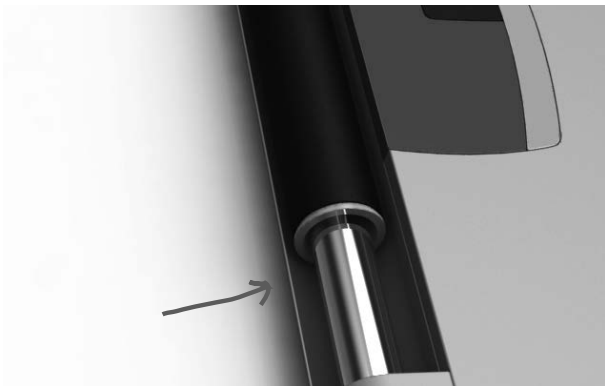


Figure 11.2 The ledge on the backside keeps the roll bar clear from any other objects.

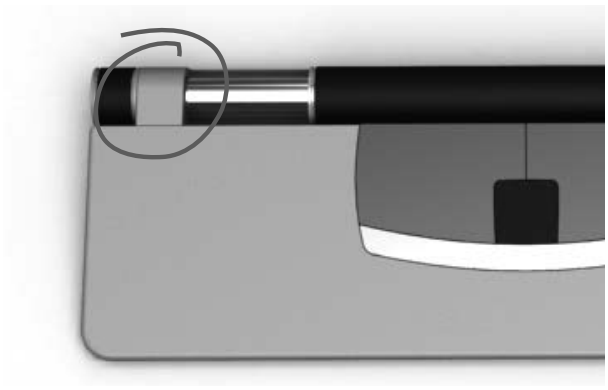


Figure 11.3 The *collars* give some support for the hands while the user is typing.

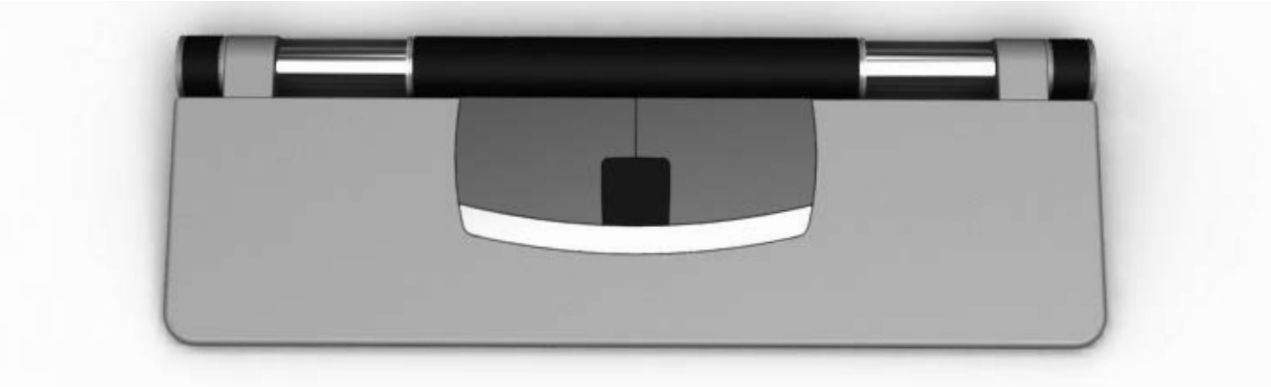


Figure 11.4 The image shows the button layout with two large main buttons, and the others less prominent.

The main buttons are large and centrally positioned, to give easy access for most users, Figure 11.4. There is also a middle button which to activate the scrolling function. Below the other buttons is a thin long button which by default is a double-click. The buttons on the smaller version had to be made smaller, due to lack of space on the flat area.

The thickness of this concept had to be remarkably smaller than the models that were evaluated in the previous chapter. By giving the roll bar a slightly smaller diameter the height of the whole device can be reduced. The new roll had a diameter of 20 mm, instead of 24, which gave the whole device a lower profile of around 23-24 mm.

The flat area (5 mm thin), which acts as a palm support, and where the buttons are also positioned, provides the user with the ability to flip the device around 180 degrees, and place it on top of a laptop (Fig. 11.5). This extends the ways the device can be used and consequently should attract more users.

The possibility to have the device upside down with buttons underneath was also explored in this concept stage, Figure 11.6. This makes the overall expression of the device much flatter which might be attractive to some users.

One of the strengths in this concept are the knobs, Figure 11.7. Situated on each side of the device they can be used for regular scrolling, but also, as mentioned in the previous section, they can be used for a great variety of other things in accordance with the user's preferences. Added to the knobs are buttons on the outside to even further enhance the potential. These buttons give the user more possibilities to customize the functions, but thanks to their location on the outside, they will not interfere with regular basic use. By that, the knobs provide the concept with high potentials of attracting many different kinds of users while still being easy to understand for a majority of the basic users.

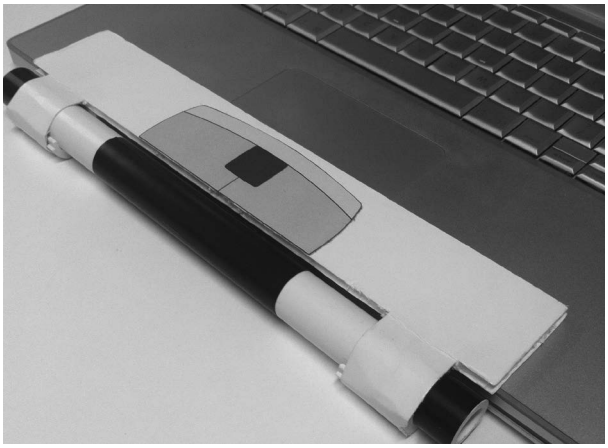


Figure 11.5 The concept can be placed on top of a laptop.

Figure 11.6 The concept can be flipped over upside down.

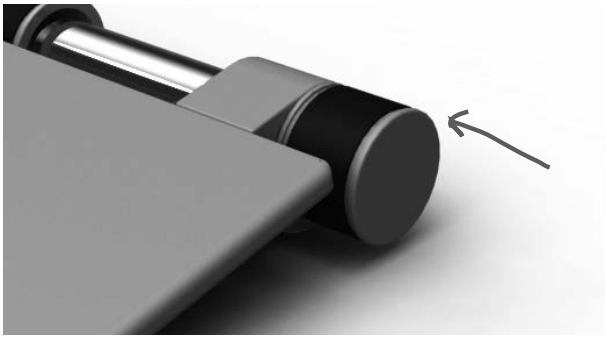


Figure 11.7 The knobs on the sides can be used to extend the functions of the concept.

12. Concept Validation

This chapter explains how the design of the refined concept from chapter 11 was validated by both users and ergonomists. Their feedback is summarized and leads to a list of which functions to keep, change or discard. The conclusions lead to the final result in Chapter 13.

The new concept was a combination of elements from the concepts in the previous phase. In order to know that this was what the users and ergonomists actually had wanted, it was important to validate the concept. At this stage the concept was more detailed and the ideas had gone through one more iteration.

The two versions of the concept were presented to the users and ergonomists with CAD-renderings and mock-ups. And the functions, both default and the more advanced, were explained.

12.1 AREAS COVERED DURING THE VALIDATION

Since the users and ergonomists have different opinions about what is important in a pointing device it was important to receive their feedback about all elements. From the users it was important to hear what they thought about the use experience, and how easy it was to understand various functions. They were asked to leave comments regarding:

- The position and size of the buttons
- The default functions of the buttons
- The general dimensions, and how it affected the reaching
- How well the design fit a keyboard and a laptop
- If it was considered portable or not
- How well the design provided support for the hands
- The idea of flipping it over the laptop case and use it reversed
- The function and position of the knobs
- Using the device upside down

From the ergonomists some covered areas were the same and some differed (highlighted in bold):

- The position and size of the buttons
- The general dimensions, and how it affected the reaching
- **The angle and inclination of the device**
- The function and position of the knobs
- **The size and position of the roll bar**
- How well the design provided support for the hands
- The idea of flipping it over the laptop case and use it reversed
- Using the device upside down
- **How well the device provided for dual hand use**

12.2 FEEDBACK FROM THE USERS

The findings from the different respondent groups showed that many things in this concept were good but that some might need to change. The user group thought for instance that the larger version provided a better support for the hands and that the size in general was nice and handy. The buttons were also mentioned as well defined.

The idea of flipping the device over a laptop was very appreciated and commented as an innovative and useful function. However, using it upside down would give no support and also the roll bar would get in the way whilst typing.

The knobs were considered intuitive and the extra functionality they would mean was appreciated. The users also had ideas about being able to detach the roll bar and bring as a simple portable device.

12.3 FEEDBACK FROM THE ERGONOMISTS

The ergonomists had some different opinions about some features. They were all consulted individually and can't have influenced each other at all.

Generally the open roll bar was appreciated because it provided good access for many situations and different users. Some respondents thought that it helped in keeping the roll and its housing clean, but others said that cleanliness isn't a big issue for many users.

The opinions varied concerning the general dimensions. Some said the small version is better because it

reduces the depth, whereas other said that the depth isn't an issue. The small version was also considered to have steep angle and that the larger version provided a good palm support. All respondents said that the low profile was beneficial.

Using the Trackbar upside down was considered non-beneficial because it gave a bad angle of attack, and provided no support for the hands. Flipping the device over a laptop was appreciated and considered a good idea.

Concerning the button layout they were generally well reckoned, except from the fact that they might have been positioned too close to the roll bar, which might lead to involuntary clicking whilst operating the roll bar. Holding a button down to activate scrolling was considered very bad from an ergonomic perspective. It leads to high stress in the fingers, and for someone having problems or suffering from discomfort in that region, it may be a very painful operation.

The knobs were highly appreciated, both their functions and their positions. They can be used with a swiping motion of the whole hand, as well as with the fingers. There might however be a risk of over use of the little fingers because of the position of the knobs. The potential of more advanced functions that the knobs provide were appreciated.

The materials of the device should be soft but still rigid, not cold or hard, and no fabrics should be used.

12.4 SUMMARY OF FEEDBACK FROM ALL RESPONDENTS

As can be noted from the results above is that the opinions regarding the size are contradictive. Some say that the small concept is preferable compared to the large version because it reduced the depth. Others preferred the large thanks to the support it provided.

Summarizing all responses lead to the following conclusions:

Ideas to keep

- Open roll bar design
- High system potential through the knobs

Ideas to cancel

- Upside-down alternative

Ideas to change

- The size. It should have a small depth, small angle and a palm support. Somewhere between the big and small concept.
- Hold to scroll is ergonomically bad. Change to another solution.
- Buttons close to the roll bar may lead to accidental pressing. Prevention needed.

Materials

- Soft or padded
- Not cold, hard or fabrics
- Rigid but soft

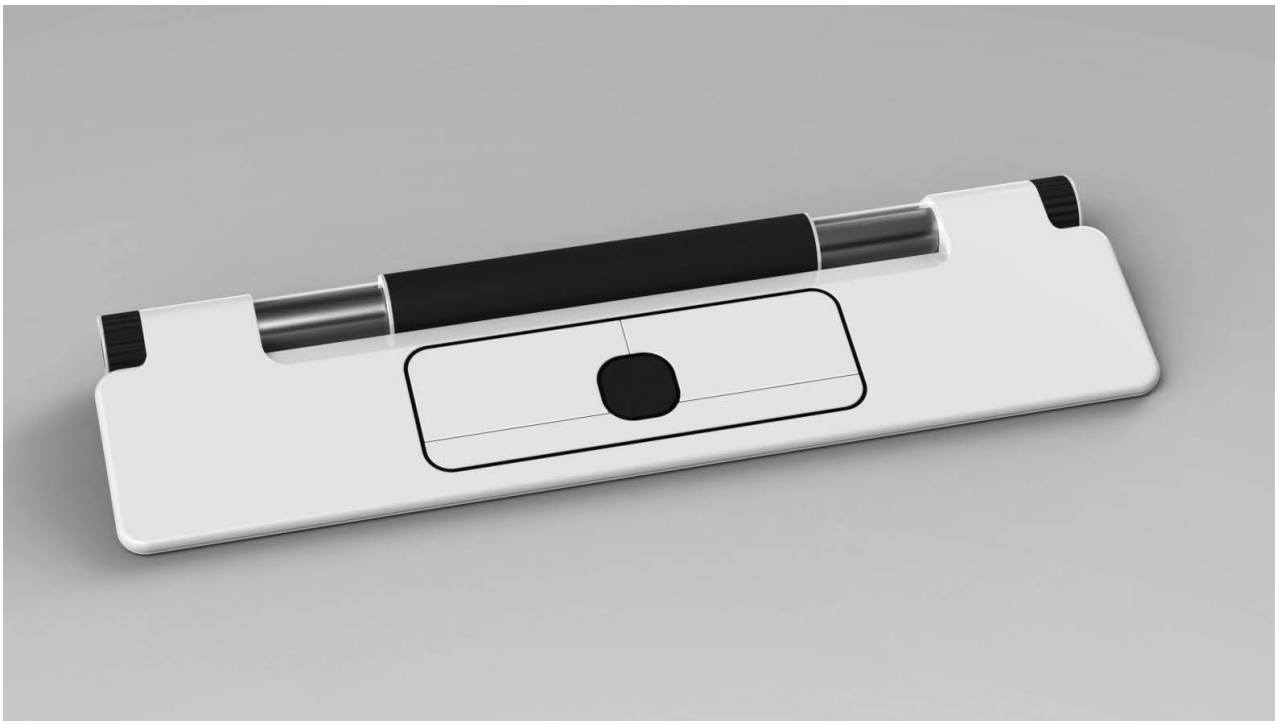


Figure 13.1 The Final result: Trackbar Express

13. Final Design: Trackbar Express

This chapter presents the final result and explains the various features. It also reveals why certain solutions were chosen and what benefits they provide.

Once the refined concept ideas had been verified some changes were done and the dimensions and all details were defined. The general shape is similar to the concept ideas, however, as can be seen in Figure 13.1, the final result has more details and some elements have undergone further refinements.

The size is now between the small and large versions from the previous chapter and consequently the depth of Trackbar Express is 80 mm. It will provide both support for the hands to some extent, but at the same time not build too much of a depth (Fig. 13.2). The width is 280 mm, which gives a comfortable width for using it with both hands and at the same time being portable. The depth and height give Trackbar Express an angle of attack of about 18 degrees, which is close to the recommended ANSI standard.

The width gives the roll bar a distance long enough to be moved along to move the cursor without hitting the ends too often. The roll bar is 120 mm long and thanks to the open design it is accessible at all times and the user can see and feel when it's near the ends.

When the roll bar reaches one of the ends there is small switch that senses the position of the roll bar and resets the position of the cursor on the screen accordingly. This way of resetting the roll bar gives the user tactile feedback, and the open design provides visual feedback. Below the

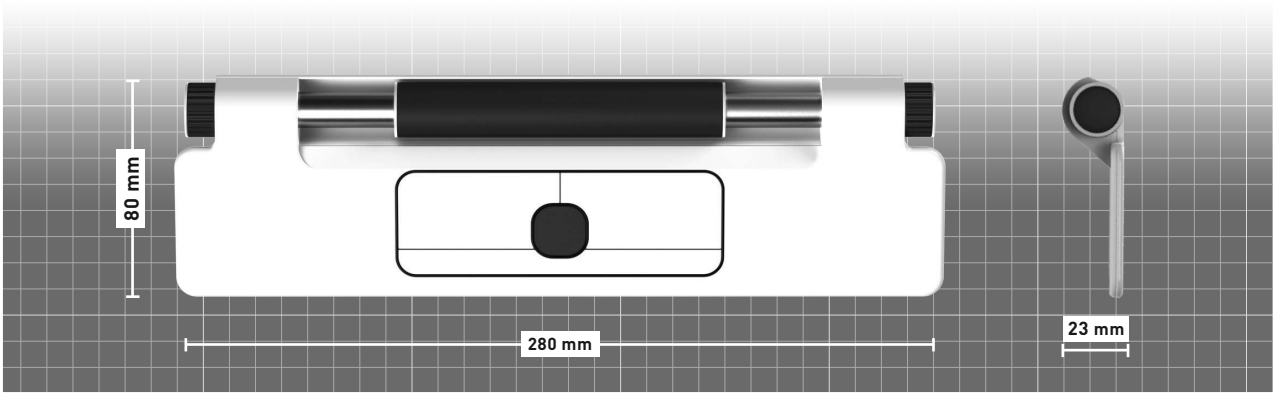


Figure 13.2 The exterior dimensions of the final result.

Figure 13.3 The picture shows the self cleaning slot under the roll bar where dirt can fall through. The USB Mini B connector is also visible.

Figure 13.5 The new design can be used flipped over a laptop, to minimize the reach.

end of the axle there is a similar clickable switch that makes the whole roll bar clickable by pressing it down.

The roll bar itself has a diameter of 20 mm, which is slightly smaller than the original version. It is however still wider than the competitors', and consequently a competitive strength, but also reduces the total height to a comfortable level. To facilitate cleaning of the product, and to prevent lint and dust from entering the house for the roll bar, a slot has been cut out in the bottom of the cylinder shaped case (Fig. 13.3). Dust and dirt can fall through the slot and is prevented from getting stuck inside the construction. Behind the roll bar the small protruding edge is kept at a thickness of 3 mm, to prevent a keyboard or laptop edge from interfering the rolling motion of the roll bar.

As with the previous concepts the final result can be used flipped over a laptop to decrease the depth as much as possible. To try Trackbar Express with a real laptop and keyboard a life-size mock up model was built as can be seen in Figure 13.5.

The button layout is designed with two large main buttons, left and right click, and below a longer button for double click, accessible with both hands (Fig. 13.4). The two large main buttons can easily be recognized as primary and secondary click, allowing the user to draw a parallel to conventional mice and thereby provide good guessability.

The double-click button is in fact two buttons in one, providing the possibility of customizing the button with more functions. The shape of the button hints that it can be used as two buttons depending on which side the user presses it, however the default function is double-click for both sides in order not to confuse the first-time user.

Just above the four buttons there is a chamfer to separate the buttons from the roll bar and thereby making the roll bar more accessible. The buttons will also less likely be accidentally pressed whilst operating the roll bar.

The scroll function is included in the roll bar, by

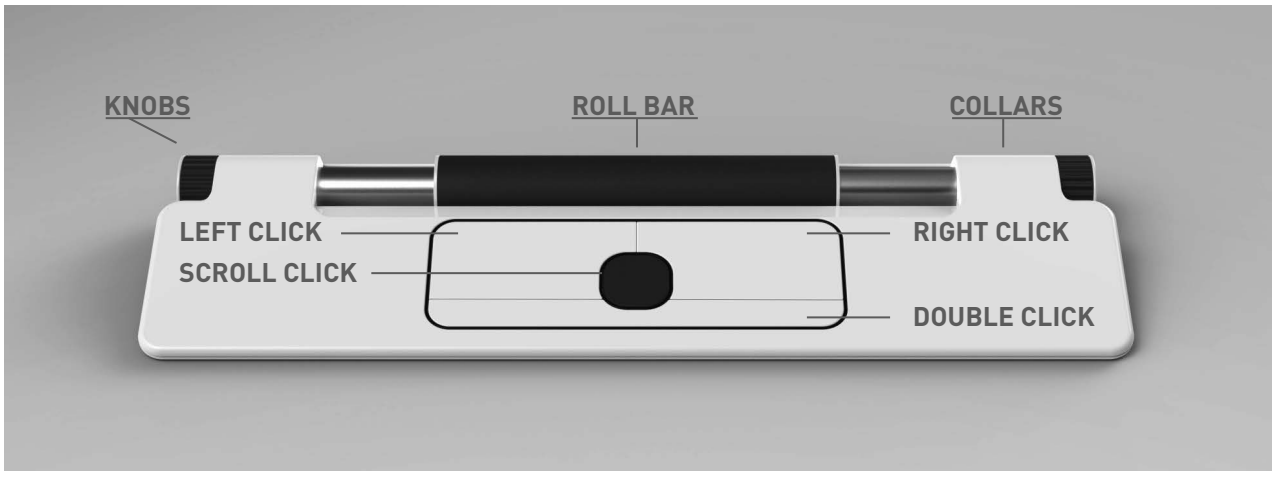


Figure 13.4 The two larger buttons are the primary functions left and right click, whereas the longer smaller button is a double click.

Figure 13.6 The image shows how the circuitboard fits in the main plate and connects to the swithces and contacts.

holding the squared button in the middle. It can also be activated by clicking it once, and then clicking it again to deactivate it, which requires less force in the fingers and causing less muscle activity. The scroll function can also be accessed via the knobs on the sides, which provides for a good dual hand use. All these ways of scrolling provides good guessability. Jordan's principle of compatibility is used to help the user guess how scrolling should be made, i.e. scrolling through the help of the middle button is related to the scroll wheel positioned as a middle button on most computer mice. The gestalt law of similarity is also implemented to guide the user, using the same material for the middle button and the roll bar to hint that they belong together. Further, scrolling with the knobs takes advantage of the gestalt law of experience since the shape invites to a turning motion easily associated with scrolling. By providing the three different ways of scrolling the risk for error is minimized.

The *collars* between the roll bar and the knobs are 30 mm wide and give the user some support for the palms, but they are still at they same height as the knobs and the roll bar, which ensures that they don't get it in the way whilst typing.

Trackbar Express is wireless and has a rechargeable battery which is charged through the mini-USB port (Fig. 13.3). Users with stationary computers also have the option to use the Trackbar plugged in at all times.

Underneath the main surface with the buttons, on the backside, there is room for circuitry and the optical sensors that read the position of the roll bar (Fig. 13.6). Cables connect the click switches and end sensors to the main circuit board.

A significant feature of the final result are the knobs on the sides, and the buttons included on their ends, since they increase the potential of the device substantially (Fig. 13.7). The knobs are 11 mm wide and have the same diameter as the roll bar - 20 mm. When turning the knobs there are small steps sensible to the user, to give a tactile feedback. The buttons on the sides act as back and forward in web browsing by default. The knobs increase the potential for the experienced user to customize personal shortcuts giving the product a high system

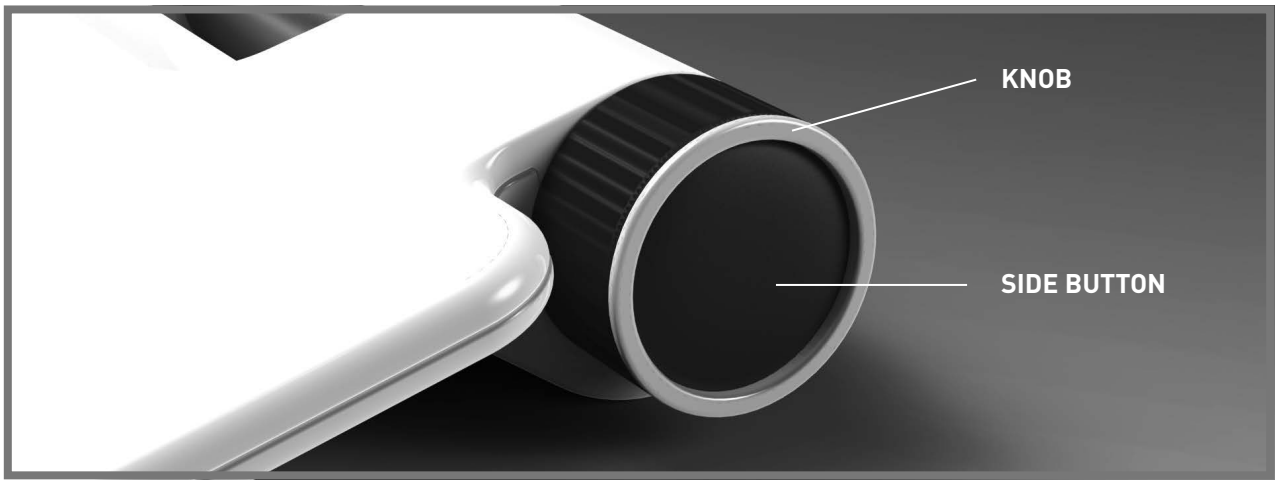


Figure 13.7 The knobs can be used for scrolling, but also for many other user customizable functions. On the ends there are clickable buttons.

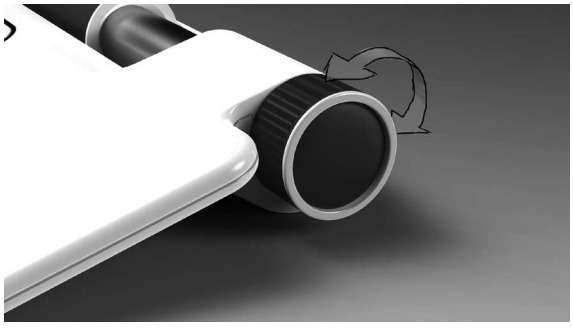
potential, and at the same time providing guessable default functions for the inexperienced user.

By default the knobs are used for scrolling, but the user can customize them through software and thereby increasing the number of functions. For example, a user working with audio production can use the knobs for volume and pitch respectively, or moving the marker in a track back an forward. For a graphic designer the knobs can be used to adjust color and zoom. A video editor might want to adjust opacity of a certain clip. For all users a drop-down menu can also be useful. By for example pressing one of the side buttons, the menu can be brought up on the screen, and then by turning the knob different tools can be selected. The knobs may also be set to adjust the sensitivity of the roll bar incrementally in several steps. The potential is great and the user has the possibility to adjust the settings to any preference (Fig. 13.8).

The customization feature can also be used to change the functions of the other buttons. The left/right click can be reversed, the long button can be changed to being back and forward in web browsing, depending on which side is pressed. The button in the middle can also be changed to any other function. Users might want to use it as a shortcut for searching, or holding it to activate a precision mode of the roll. The potentials are endless and all users should be able to find a preference that fits them.

1. In graphic software the user can choose to access many features by pressing the side button on the knob.

2. When the button is pressed a menu appears showing which tool is currently selected.



3. By turning the knob a new tool can quickly be selected, and the user doesn't have to move the hands to the keyboard.

Figure 13.8 The knobs can be used to access many features, for example a user customized drop-down menu.

Since Trackbar Express has an open design, the roll bar needs to be protected somehow during transportation. To provide this protection a sleeve can be designed as proposed in Fig. 13.9. The sleeve not only offers protection for the Trackbar Express, it also adds two other features. It can be used as a hand support while the product is used, by opening the lid and keeping the sleeve on. Further, the lid can be used to raise the keyboard if a thin keyboard is used.

The sleeve could be made out of a soft material like neoprene or leather.

Figure 13.9 A sketch proposal for a sleeve solution, protecting the device during transportation and adding extra features.

14. Conclusions

A summary of the final result and conclusions on what was achieved by the new design.

The purpose of the thesis was to methodically develop a re-designed version of the existing Trackbar Emotion. The aim was to find a design that meets both existing and new reactive users, with already developed disorders, and also attract people to use it in proactive care.

The slim design with a low profile and a roll bar that is large and easy to reach makes it fit most work stations. It reduces the depth and consequently the reach.

Trackbar Express has a centered position which facilitates comfortable use and the use of both hands.

The position and layout of the roll bar, buttons and knobs make it easy to use for novel users, which opens up for a broad market with many users.

Albeit its ease of use, the Trackbar has a large system potential, thanks to its customizable features, allowing demanding users to have advanced input methods.

The design also provides the user with the ability to place it on top of a laptop, which minimizes the depth for that use scenario.

The final result is presented with defined dimensions and functions, which are feasible and realizable. The output is however not ready for manufacturing, where more work needs to be done to design the electronics and the different parts in the design.

The authors believe that they have met the aim of the project by designing a roll mouse with new smart functionality that differs from the other products on the market today. And since EuroOffice's aim is to provide an affordable alternative, that can be sold in consumer stores, providing Trackbar Express in different colors, Figure 14.1, might draw attention and attract new users. These people will become aware of the problem and might buy the product and use it in preventive care.

The design together with the functionality and the low price will help to categorize Trackbar Express as a new computer tool, instead of a medical aid product designed for people with problems.

Figure 14.1 Trackbar Express can be prodcued in many colors to attract more customers.

15. Discussion

This chapter lets the authors question the results and the process.

15.1 FINAL DESIGN

The final design is elaborate and it is the result of many iterations and user evaluations, but there are some things that need to be discussed.

15.1.1 Form

The final design needs to be evaluated more with physical models to find the perfect size that fits a broad spectrum of users. It also needs to be evaluated for manufacturing. The design is made as thin and compact as the authors believe is possible with the present manufacturing techniques for Trackbar Emotion. The decision on making it as thin and compact as possible comes from the functionality, both of being able to turn it around and put it on top of a laptop and because of user needs.

More work could have been made with the visual identity of the product, the result is formed by functionality and thereby creates a new identity. The design is something new and is differentiated from other CPD's on the market. The form could have followed Trackbar Emotion more, but the authors wanted to keep a simple and honest expression with geometrical shapes. Further, Euro Office has no clear visual brand identity that could be followed; their two products Trackbar Pro and Trackbar Emotion don't follow the same visual expression.

15.1.2 Roll bar

Since the Trackbar has an open roll bar and is supposed to be portable, something has to be done to prevent the roll bar from moving while carrying it around. The authors have an idea of using a neoprene sleeve that also may be used as a soft support while using the product. However, much more work needs to be done to develop this sleeve.

15.1.3 Buttons

The final design makes it possible to develop different button layouts. The same circuit board can be used, and by changing the top shell and the buttons, the design can be differentiated into more products.

15.1.4 Knobs

The knobs add a great system potential for the advanced user and at the same time they can be used by everyone for scrolling. However, the ergonomics regarding the knobs is still a question mark and the product needs to be tested to see how the user will interact with it. There is a risk that the knobs might invite the users to use their little fingers and reach for them, but they make the product flexible and bring a high potential to the product.

15.1.5 Ergonomics

To further evaluate the ergonomics of the design a model needs to be made, but the important ergonomic factor to remember is that the design is built on the CPD-methodology. The authors believe that the cognitive ergonomics of the design is good. However, this should also be evaluated by allowing users to try the product.

15.1.6 Technical aspects

Technical aspects such as manufacturing and fitting of circuit board and components have been considered when developing the design, but no decisions regarding it has been made and further work needs to be made to make everything work.

15.1.7 Material

Regarding the materials of the product no final decisions were made, some recommendations were given by ergonomists during the project. However, the material should be decided upon when the manufacturing is decided.

15.2 METHODS AND PROCESS

Product design is not a linear process and the authors believe that the final design benefits from all the iterations in the conceptualization process. Some methods used might seem a little unnecessary in retrospect, e.g. the EMG-tests which proved to show no useful results.

15.2.1 Defining user groups

It was hard to define the target group since there are so many computer users and they are all different. Therefore it took a while before the user groups could be defined properly. It would have been easier to carry out the user studies if the users were defined earlier in the process.

15.2.2 Informal user tests

At first it was decided to do a structured usability test, but it was soon realized that it would be hard to design a test that could help identifying the errors of use since the device is always used together with software.

Many users participated in the informal user test, but it was not a representative group of people. Everyone was between 20 and 30 years old and probably had great or above average computer skills. It was good in the way that they think of things that an inexperienced computer user might not consider. At the same time they have more demands on a pointing device than other users, which led to a lot of comments and focus on the precision of the control of the cursor.

All of the tests were carried out on laptop computers and no test was made on a stationary computer. This led to a lot of focus on the integration with a laptop, including a lot of reaching and the issues of the height of the device. In hindsight more testing together with stationary computers could have been beneficial for an accurate outcome of the method. However, the product should work well with a laptop, especially since Euro Office considers portability to be a competitive advantage. Furthermore, the laptops were Apple computers operating in a Mac OS X environment, where some of the functions don't work. It probably would have been better to perform the tests or at least some of them on Windows computers, but it is still important to consider other users, especially Mac users since they are a growing number.

15.2.3 Focus group with reactive users

The users participating in the focus group were all architects, which was good because a lot of good feedback was received. However, it might have influenced the result somewhat since they have another relation to shapes and colors and they were probably more skeptical than other users might have been. They considered all of the products to be ugly and focused a lot on the physical appearance. This wasn't all bad since it was understood that if these users could be attracted to the product, the broader mass would probably be attracted as well.

15.2.4 Long-term testing

The first long-term test initiated in the beginning of the project was carried out to get a deeper understanding of the initial user experience and the users' acceptance of the products. However, the test did not give as much as hoped. The users gave up too fast and did not use the products all the time as they were asked to do. The test might have given better results if the participants had the products for a longer period of time. Furthermore, the users were given different products which made it harder to compare the results.

The second long-term test proved to be much better. Here all users had the same product and instead of just filling out a journal they were gathered for a focus group meeting, which made it much easier to get the users' opinions. It was good to do a test with several Trackbars, but it would have been better to do it earlier in the project. The second long-term test did not give that much new data, it rather confirmed issues detected earlier in the user studies. However, it proved to be very useful to have the participants as a reference group later in the project to help evaluate the new concepts.

15.2.5 Concept evaluation

No structured methods were used to evaluate the concepts, but using the long-term test participants, the ergonomist at Stanford and the Ergonomics Roundtable as evaluators gave a lot.

When evaluating the concepts with the users in the focus group, some things could have been done differently. For practical reasons too little time was used to discuss the five concepts. Some concepts were given more time than others and that made it hard to cover everything. Showing models of the concepts proved to be very good, so the users could touch and feel the shapes and sizes. But more models in different and more accurate sizes should

have been used and the focus group should have focused on just this.

The illustrations of the button layouts were not used very much. It would probably have been better to have the buttons marked out on the prototypes instead.

The level of details in the sketches could have been lower to show the users that the ideas were on a conceptual level. They were too detailed and the users did not understand that a function in one concept could be used in combination with another concept. However, a lot of useful feedback was given anyway, it just had to be analyzed in a different way.

15.2.6 Prototyping

Doing the design work at Euro Office in California meant poor possibilities to build physical mock-ups which may have influenced the result somewhat. The design of hand operated products benefit from prototyping, since the size and physical interaction can be evaluated much easier than with sketches.

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Appendix 1 - Web Survey, page 1

Frågor om användning av ergonomisk datormus

Vi bedriver just nu vårt examensarbete inom Teknisk Design på Chalmers, där projektet går ut på att utvärdera datormöss, vilkas syfte är att avhjälpa och förebygga fysiologiska problem benämnda som *musarm*. Resultatet kommer att användas till att förbättra en modell så att både ergonomi och användbarhet blir optimerade.

Vi uppskattar om du tar dig tid att svara på nedanstående frågor angående dina erfarenheter och upplevelser om någon eller några av produkterna.

Tack för hjälpen!

Daniel Amosy och Jonatan Hedin Persson

- Hur många timmar arbetar du vid datorn en normal arbetsdag?

Fyll i ditt svar här!

- Vilken typ av arbete utför du vid datorn?

Fyll i ditt svar här!

- Vilken/vilka av följande produkter har du använt?

Fyll i ditt svar här!

Mousetrapper

Barmouse

Nomus Navigator

Trackbar

Rollermouse

Appendix 1 - Web Survey, page 2

- Vad var anledningen att du började använda den? (Smärta/obehag, alltså musarms-syndrom, tilldelad via arbetsgivare, rekommenderad av vän etc...)

Fyll i ditt svar här!

- Beskriv hur du upplevde produkten med avseende på:
  - **Knapparna** (Beakta faktorer såsom material, form, placering, känslighet i klicket, funktionen etc...)

    Fyll i ditt svar här!

  - **Styrrullen/-plattan** (Beakta faktorer såsom material, form, placering, känslighet i klicket, precisionen etc...)

    Fyll i ditt svar här!

  - **Arm-/handledsstöd** (Beakta faktorer såsom material, yta/textur, form, placering, nyttan etc...)

    Fyll i ditt svar här!

  - **Scrollhjulet** (Beakta faktorer såsom material, yta/textur, form, placering, känslighet, precision, känslan i klickfunktionen etc...)

    Fyll i ditt svar här!

  - **Helheten** (Beakta storlek, form, utseende, färg, yta/textur, material etc...)

    Fyll i ditt svar här!

- Skulle du kunna rekommendera musen till någon? På vilka grunder?

Fyll i ditt svar här!

- Skulle du kunna tänka dig att börja använda någon av de övriga avbildade produkterna? Motivera!

Fyll i ditt svar här!

Appendix 2 -Long term use test

Enkät

Börja med att svara på frågorna på första sidan, anteckna sedan i boken varje gång du stöter på något problem med användandet eller om det är något som inte fungerar som du vill. Anteckna även gärna de positiva upplevelser du har!

Produkt _____

Hur många timmar per arbetsdag spenderar du framför en dator?

☐ 1 - 2 h ☐ 2 - 4 h ☐ 4 - 8 h ☐ 8 eller mer

Vad använder du för operativ system?

☐ PC ☐ Mac ☐ Linux ☐ Annat

Beskriv din arbetsplats (stol, arbetsställning, skrivbord osv):

Upplever du eller har du upplevt smärtor i samband med datorarbete (om ja: beskriv)?

Har du använt liknande produkter tidigare (om ja: vilken)?

Första intrycket

Beskriv ditt första intryck av produkten (interaktion, fysisk upplevelse, känslor, form, färg, material etc.):

Upplevelselogg

Datum Beskrivning

_____ _____

Hur fick det dig att känna dig?

Datum Beskrivning

_____ _____

Hur fick det dig att känna dig?

Datum Beskrivning

_____ _____

Hur fick det dig att känna dig?

Intryck efter en vecka

Beskriv ditt intryck av produkten efter en veckas användning (interaktionen, fysisk upplevelse, känslor), var noga med att få med förändringar från ditt första intryck:

Tack för din medverkan!

Jonatan Hedin Persson & Daniel Amosy

Appendix 3 - Trackbar test checklist, page 1

Pre study questionnaire
Please take your time to answer these questions, try to describe as detailed as possible.

Name (this will not be published in the Master Thesis report):

_____

Age: _____

What kind of computer work do you do on your computer (software/applications etc)?

_____

_____

_____

How many hours a day do you spend working on your computer at work?

☐ 1-4 hours ☐ 4-8 hours ☐ 8 or more

How many hours a day do you spend working on your computer at home?

☐ 1-4 hours ☐ 4-8 hours ☐ 8 or more

Description of workstation

Desk (e.g. shape, height, size): _____

_____

Chair (e.g. adjustable height, armrests): _____

_____

What kind of computer do you use?

☐ Desktop ☐ Laptop ☐ Both

What operating system do you use?

☐ PC ☐ Mac ☐ Other: _____

Appendix 3 - Trackbar test checklist, page 2

What type of mouse do you use?

_____

Do you frequently use keyboard shortcuts? (e.g. save, copy, paste etc)

_____

Ergonomics

What do you know about ergonomics?

_____

_____

Have you ever experienced any discomfort in the hand, wrist, arm or shoulder region while working at your computer? Please describe.

_____

_____

_____

If so, have you ever consulted a doctor about your injury?

_____

Have you ever been to an ergonomist to get an ergonomic assessment?

_____

Have you tried a centered pointing device before? What kind?

_____

Thank you for your participation!

Daniel & Jonatan

Appendix 4 - Complete List of Functions

FUNCTION	W	COMMENT	CATEGORY	REACTIVE USERS	PROACTIVE USERS	VOLUN-TARY	INVOL-UNTARY	MOBILE	STATION-ARY	HIGH PRECISION	STANDARD PRECISION	PHASE: POINT OF SALES	PHASE: FIRST TIME USE	PHASE: LONG TIME USE	ORIGIN
reduce number of clicks	4		clicking	1	1										Need
reduce click stress	5		clicking	1	1										Need
give feedback to input actions	3,5	both clicking and movement	clicking	1	1								1		Need
provide easy and intuitive access to primary-click	3	observed that users wanted to primary-click with rollbar	clicking		1		1					1	1		informal tests
provide voice control	2		clicking	1											focus group
enable drag-and-drop function	3,5		clicking	1	1					1					informal tests
enable page scrolling	5		clicking	1	1	1	1	1	1	1	1	1	1	1	main function
enable click control	5		clicking	1	1	1	1	1	1	1	1	1	1	1	main function
allow standard precision control	3,5	cursor movement	cursor control		1						1		1		Need
allow HIGH precision control	3	adv	cursor control							1					Need
enable cursor control	5		cursor control	1	1	1	1	1	1	1	1	1	1	1	main function
provide customization of input actions	3,5		customiza-tion		1					1				1	Need
facilitate shortcut usage	4	adv	customiza-tion							1				1	Need
fit dual-screen setup	2		customiza-tion							1					Need
provide comfortable support	4		material	1	1		1		1						Need
reduce self noise	3	quality perception	material									1	1		Need
be durable	2	sustain wear over time	material					1						1	focus group
minimize friction in contact surfaces	3	arm and hand supports should not attach to skin	material	1	1										previa
easy to connect/discon-nect	3		other					1					1		Need
allow hands to operate in a centered position	5		shape	1	1							1			Need
facilitate a neutral working posture	5		shape	1	1							1			Need
allow a relaxed posture	5	provide support for forearms	shape	1	1										Need
allow use with two hands	4		shape	1	1										Need
allow use with only one hand	5	left or right	shape	1	1										Need
support anthropometric variations	4	allow users of different body dimensions to operate	shape	1	1							1			Need
facilitate use with keyboard	4	minimize distance. Height equal	shape	1	1								1		Need
fit desktop workplace	3	size, desk, posture etc.	shape						1				1		Need
be portable	4	minimize size and weight	shape					1				1			Need
fit laptop use	4	height and dist. to keys	shape					1							Need
Avoid repetitive motions in limbs	5	for example moving the arm back and forth in different positions	shape	1	1										Previa
enable use with an ergonomic keyboard	2		shape	1	1										questionnaire
provide stability in device	4		shape/ material	1	1										Need
enable easy cleaning	3		shape/ material											1	informal tests/ questionnaire
communicate ergonomic benefits	3	by aesthetic means	styling	1	1							1	1		Need
fit workplace	3	aesthetically appealing	styling		1		1					1			Need
communicate quality	3		styling		1					1		1	1	1	Need
provide guessability	3	intuitive default functions	usability		1		1					1	1		Need
provide efficiency in use	5	low effort to accom-plish the goal	usability	1	1										Need
provide high system potential	3		usability							1				1	Need
provide recognition	4	user can associate functions and buttons to buttons on other products	usability									1	1		

Appendix 5 - Revised List of Functions

FUNCTION	W	COMMENT	
provide double-click function	4	double-clicking leads to peak loads that should be avoided	
light click pressure	4	the clicking pressure of the buttons should be between 50 and 70 grams	
enable primary and secondary click	5	main function	necessary
enable page scrolling	5	main function	necessary
enable cursor control	5	main function	necessary
enable customization of input actions	4	for the advanced user. a good software can give the product a high system potential	
provide support for hands while mousing	4	use soft parts of hands as contact surface	
provide support for forearms while typing	4		
provide wireless option	3		
allow hands to operate in a centered position	5	main function	necessary
allow use with two hands or either	4	flexibility so that the user can vary his/her posture	
be portable	4	dimensions	
minimize height	4	in order to fit laptops and slim keyboards and so that the product is not in the way while typing. Height of rollermouse = 25 mm	
minimize depth	4	to avoid reaching and thus move the elbows out from the body while typing	
enable easy cleaning		of surfaces and rollbar	
provide guessability	3		
provide high system potential	4		
provide efficiency in use	5		
facilitate shortcut usage	3		
provide easy exchange of batteries	3		
have thicker rollbar than competitors	4	TB is 23,6 mm today. This is an advantage over competitors, but it could be smaller.	