Critical dimensions and usability factors for navigation devices on mobile phones

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Abstract

The purpose of this thesis was to create usability guidelines when designing the hardware of mobile phones at Sony Ericsson Mobile Communication (SEMC), a leading developer of mobile phones.

As the users request larger screens, and yet smaller mobile phones, components such as the keypad and navigation device are being limited to a much smaller area than offered today. The challenge with this approach is how to maintain its ease of use.

Industrial designers and product planners at Sony Ericsson only have a limited amount of time when developing a new mobile phone and therefore not having the time for multiple iterations with focus on ergonomics. By producing easily accessible usability guidelines, the time for development and good ergonomics may be ensured.

This thesis report starts with a focus on the overall hardware usability but is then narrowed down to the navigation device of the mobile phones. To solve the problem statements a literature research and benchmarking of current mobile phones were conducted, followed by a extensive usability test.

From the usability test, it was found that there was no difference between the navigation of mobile phones, whether using a joystick or a rocker key. It was found that people with large thumbs were performing worse than people with small thumbs, leading to the conclusion that every millimeter is important. Another observation made was that some of the small navigation devices with a good topographic design performed better than larger ones, indicating that the design of the navigation device is more crucial than its size.

At the end of this report, ergonomic guidelines for navigation devices are presented, intended to be used for developers at Sony Ericsson Mobile Communication.

Sammanfattning

Syftet med det här examensarbetet var att utarbeta hårdvaruguidelines i användbarhet för mobiltelefoner som ska användas i designprocessen hos Sony Ericsson Mobile Communications (SEMC), ett ledande företag inom mobilindustrin.

När användare efterfrågar större skärmar och mindre telefoner på samma gång blir komponenterna såsom knappsatsen och navigationsknappen förpassade till en mycket mindre yta. Problemet med detta är att telefonerna fortfarande ska vara lätta att använda.

Industridesigners och produktplanerare på Sony Ericsson har kort tid på sig att ta fram en ny modell och har därför inte tid med flera iterationer i designprocessen. Genom att ta fram lättillgängliga guidelines kan bra ergonomi uppnås, samtidigt som tiden för designprocessen inte påverkas.

Rapporten börjar med fokus på användbarhet i allmänhet på hårdvarudesign, men koncentreras senare kring navigationsknappen. För att lösa problemställningen utfördes en litteratur studie, mätningar på existerande telefoner samt ett omfattande användbarhetstest.

Användbarhetstestet visade att det inte var någon skillnad i prestation mellan joystick och rocker key när användarna navigerade medan de tittade på skärmen. Användare med stora tummar gjorde fler fel än användare med mindre tummar, vilket ledde till slutsatsen att varje millimeter är viktig. Vissa små navigationsknappar presterade bättre än stora navigationsknappar vilket indikerar på att det är knappens design är viktigare än dess storlek.

I slutet av rapporten presenteras guidelines till utvecklare på Sony Ericsson.

Glossary

Here is a brief description of the terms used in this master thesis:

Affordance – Attribute that encourages the user to perform a specific action, e.g. a key that invites the user to depress.
ANOVA – Analysis of variance between groups. This method is used to test significance between groups.
Clamshell - A foldable mobile phone.
Click ratio – The definition of click ratio is the "max force needed to press before the key activates minus the force needed to press when the key is activated, divided by the max force".
CSK - Centre selection key of a rocker key.
Direction Key – The direction key is the key used when navigating on a rocker key.
Ease of use – Ease of use is defined in this test as "The navigation device is reacting the way the user expects it to react, providing the users finger a comfortable feeling and performs the task with maximum efficiency".
Heads up – Navigating without looking at mobile phone.
Joystick – A navigation device that uses a stick for navigation.
Mann-Whitney – Non-parametric statistical significance tests. This method is used to test significance between non-parametric groups as ranking of the mobile phones.
Mapping – Providing information of what a function does, e.g. arrows on a key indicating the direction.
Rocker key – A navigation device that uses a key with several directions.
Stick phone – A mobile phone that can not be folded.
Tactile Information – Texture or roughness that the finger feels.
Tactile Feedback – Tactile feedback is force perceived by the finger indicating that the system has recognized the key as depressed.
Usability – Attribute that describes how easy a product is to use

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1. Introduction

The purpose of this thesis was to create usability guidelines when designing the hardware of mobile phones at Sony Ericsson Mobile Communication (SEMC), a leading developer of mobile phones.

As the users request larger screens and smaller mobile phones at the same time, components such as the keypad and navigation device will be limited to a much smaller area than offered today. The problem with this approach is how to ensure ease of use. Today, industrial designers and product planners at Sony Ericsson only have a limited amount of time when developing a new handset and therefore not having the time for many iterations to reach ergonomics of design. By producing easy accessible usability guidelines the time and development of sufficient ergonomics may be ensured.

1.1 Purpose and Problem statements

Following presents questions that need to be investigated in this thesis.

- What guidelines exist today?
- Is there a difference in performance when navigating using a rocker key or a joystick?
- How does the shape of the navigation device affect usability?
- How does the size of the navigation device affect usability?

2. Method

The following steps were conducted throughout the thesis work:

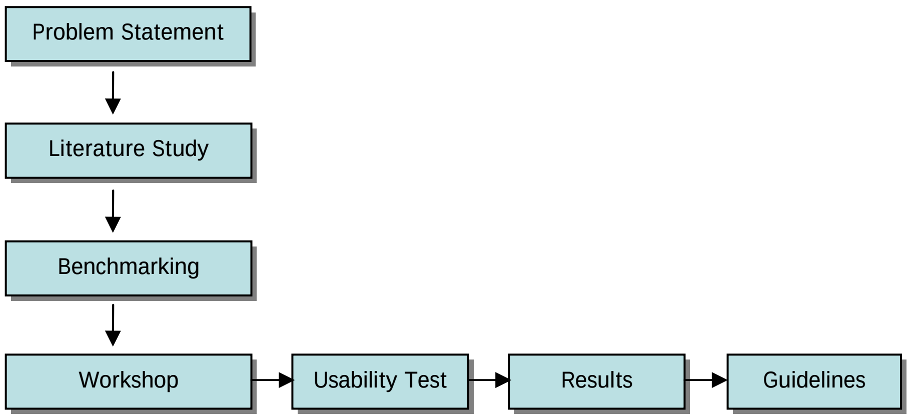

Figure 2.1. Topics in the thesis work.

In the first step the problem statements of the thesis work was defined. To get a background what hardware usability is about and what guidelines that exists for the development of the current mobile phones a literature study was conducted. After this research, the next step was to measure the existing mobile phones to see if they consented with the guidelines. With this knowledge, hypotheses about hardware usability on mobile phones were developed through a workshop. Since the hypotheses covered a too large sphere compared to the time available for the thesis work, the following steps focuses on the field that was most important for Sony Ericsson, navigation devices. To test these hypotheses usability testing was chosen as the most appropriate method. The results from the entire process were put together as guidelines for developing new navigation devices for Sony Ericsson.

3. Literature study

A literature research was conducted to achieve the necessary background of hardware usability on mobile devices. Also, a short introduction to usability testing is presented, which is a common way to evaluate products.

3.1 Ergonomics in design of mobile devices

This topic includes areas such as design of keypads, navigation devices and grip and form of mobile phones. This research describes different factors affecting the usability of hardware design of mobile phones. In the first part of the research distances between keys, layout and what affects them are discussed. Further, it describes how the key itself should be designed for achieving good usability. When to use a joystick as a navigation device and what minimum dimensions for handling a rocker key are shown in the next topic, followed by a discussion concerning activation feedback and important parameters affecting it. The final topic considers grip and form of mobile phones.

3.1.1 Keypad Design

One of the problems the mobile industry is facing is that the displays are getting bigger and the mobile phones are becoming smaller, which results in less space for the keypad. Due to this problem the distances between keys and the sizes of the keys reduces and affects the usability in a negative way. A smaller keypad demands good tactile feedback to increase usability so the user can navigate her/his way to the right key. By creating a topological keypad, meaning placing keys strategic and emboss them, the user perceives the keypad to be bigger than it really is. Keys providing the same service should be grouped together and have the same appearance.

Today's guidelines regarding keypad design is limited and it is really hard to find guidelines considering keypads on mobile phones. Some guidelines found on small keypads are obtained from studies on pocket calculators and similar devices. These are interesting because their sizes are similar to a mobile phone. Pocket calculators have a different keypad arrangement of the numerals, compared to a mobile phone, see Figure 3.1. The arrangement of a pocket calculator is less effective due to errors made while typing [5, 6]. It has been made quite a lot of studies on QWERTY keyboards (a typical computer keyboard), but since they have such a large area with many more keys, these are not that interesting for this research. Another aspect is that all fingers are used when typing on a computer keyboard, but pushing keys on a mobile keypad is usually done by one or two fingers. Young people usually push the mobile keys with their thumbs while elderly people tend to use their index finger [7].

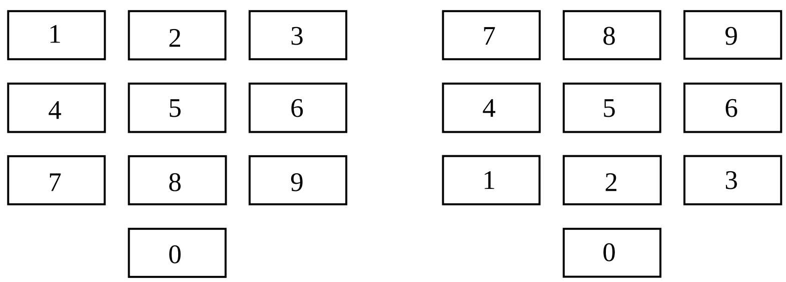

Figure 3.1. Difference in layout between a phone and a calculator were the one to the left has a phone layout.

When designing a keypad the size of fingers must be considered. Men, women and young teenagers differs in thumb size [3, 4] and it’s crucial to have this in mind because making a keypad for young teenagers would maybe not be a good keypad for a fully grown man from a usability perspective. Differences between men and women’s finger size are presented in Table 3.1:

Table 3.1. The median of men and women’s width of thumb and index finger in millimeters.

Source	Finger	Men	Women
Body Space, 1990 [4]	Thumb (mm)	23	19
	Index finger (mm)	21	18
Human Scale, 1993 [3]	Thumb (mm)	23	20
	Index finger (mm)	18	15

As mentioned earlier the distance between the keys decreases in the mobile industry and existing guidelines are old. During the literature research following measurements were found and are shown in Figure 3.2 and Table 3.2.

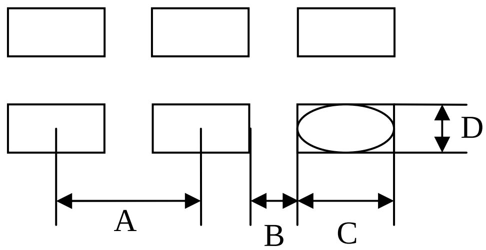

Figure 3.2. Dimensions related to Table 2.2.
The key can also be oval as illustrated.

Table 3.2. Guidelines on keypad dimensions.

Source	[1] Pocket calculator			[2] Push key			[3] Pocket calculator		
Dimension	Min	Max	Opt	Min	Max	Opt	Min	Max	Opt
A	12			25					
B				15	22		3,8		
C				10		12-25			
D				10		12-25	2,5		

Source	[6] Numerical keypad			[7] Mobile phone		
Dimension	Min	Max	Opt	Min	Max	Opt
A	9,8		19			
B	3,3		6,5	5,6	7,5	
C	6,5		13			
D			13			

As seen in the table most of the dimensions are related to the width of the keypad and one thing to have in mind is that it is not the width of the keypad that is critical on a mobile phone. The length is critical due to that the displays are getting larger. More data considering the vertical distances were unfortunately not found.

3.1.2 Key shape and label design

If the keys on a keypad have a poor design from a usability perspective the entire keypad loses its value for the user, not complying with easy text and numerical input. There are a number of factors that can be considered to make the keys well designed. This section is going to evaluate two key factors existing in literature that are the most important for making the keys easy to use.

Depending on cultural heritage people are familiar to different shapes of keys. For example, Germans are more satisfied using keys shaped round or oval compared to Americans [8]. Why this is the case will not be discussed in this report.

Keys with similar tasks should have the same appearance to avoid confusion and provide good affordance to the user, by choosing the appropriate colour, material and shape for the key. Labels on keys should be readable by having a sharp contrast, the font should be minimum 10-12 points (3.5-4.2 mm) according to a research on smartphones [8].

The top area of the key can be flat, convex or concave. Convex or flat keys should be used according to one publication [7] but according to another source [8], the keys should be concave or flat. The difference might depend on that the source [8][1] is based on smartphones and they tend to be a little bit bigger than normal stick phones, especially a couple of years ago. However, today it is favoured to use convex top areas for smaller keypads because it increases the efficient distance between keys, see Figure 3.3.

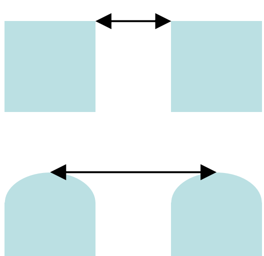

Figure 3.3. Efficient distance between convex and flat keys.

If the diameter of the key is larger than 10 mm the top area should be concave. This is more comfortable for the fingers because they can fit inside the keys.

[1] Publication last updated 2001.

3.1.3 Navigation Device

Today the most frequently used key on mobile phones is the navigation key. There are mainly two different types of navigation; two and four-way navigation. Two-way navigation is used in less complicated menu systems when the user only can move up and down in the menu. This can be accomplished with the help of a two-way key or a scroll wheel that can be pressed. When moving up and down in the menu system there is no need for using a joystick. The phones are getting more complex and so are the menu systems allowing more functions. The newer menus based on icons, see Figure 3.4, render the possibility of four-way navigation (up, down, left and right). This is most commonly accomplished by either a rocker key or a joystick, see Figure 3.5 and Figure 3.6.

Figure 3.4. Icon based menu.

Figure 3.5. Rocker key

Figure 3.6. Joystick

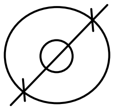

Figure 3.7. Minimal dimension for a rocker key

The minimal dimension for a rocker key with a centre key is illustrated in Figure 3.7. This diameter is based on test results from usability tests conducted at Sony Ericsson [9]. If there is a rocker key without a centre key the diameter could be narrowed down to a minimum 12 mm. The rocker should provide good mapping and affordance e.g. equipped with arrows and slightly elevated at the position where to be pressed.

According to [9], a rocker key is preferred for easy to use phones due to recognition, reliability and less precision. When there is not enough space for a rocker key, a joystick is an option as navigation device. The top of the joystick should be made of an abrasive material e.g. rubber to get a good grip which increases the usability and will minimize the risk of navigating the wrong way. No data concerning the optimal or minimal size of a joystick, used on small devices such as mobile phones, has been found.

3.1.4 Activity Feedback

Feedback from a keyboard or keypad could be divided in four separate categories:

- Visual feedback
- Acoustic feedback
- Tactile feedback
- Kinesthetic feedback

Visual feedback could be a display of numbers on a screen when activating a key. Acoustical feedback means that the user receives an audio confirmation when a key is pressed, either by a mechanical clicking sound of the keys or sound implemented in the software. Tactile feedback is force perceived by the finger indicating that the system has recognized the key as depressed. Kinesthetic feedback is the movement the finger can feel.

According to the literature, feedback is one of the most important issues in interaction design [10]. With that knowledge it would be logical to implement different kinds of feedback on a keypad. Different studies on keyboards have shown that there is no obvious correlation between typing performance and feedback. According to the studies, a lot of factors depend on the performance when typing, e.g. the users typing skills, type of keyboard, etc. One article [13] that discusses the major issues of keyboard design concludes after some tests that feedback has “little effect on performance on experienced operators”, but that “visual feedback appears to be important during training”. A study [14] noticed a minor improvement on keyboards with auditory feedback. However, one study focusing on membrane keypads (2) [15] has found that tactile feedback provided by metal domes improved keying performance. Most of the articles agreed that feedback is more important during the learning phase.

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[2] Membrane keypad is a keypad that doesn’t have physically separated keys (might be visually separated). The keys are printed on a thin non-conductive layer instead. This is how the majority of mobile phones are created today, see picture Figure 3.8

One attribute that affects the kinesthetic feedback is key travel distance (the distance for the key between standard position to the depressed position), until it reaches the lowest position. On an ordinary keyboard the keys are separated with a travel about 1.27-6.35 mm which gives a good kinesthetic feedback. Studies have shown that too low or too high travel of keys results in slower performance [12]. This is not applicable on membrane keypads since they have less possible travel distance because of their size.

Figure 3.8. Membrane keypad

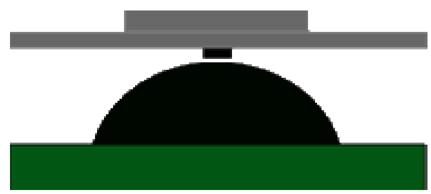


Figure 3.9. A key on top of a metal dome. When pressed with a specified force the metal dome (black) depresses

Tactile feedback can be accomplished on membrane keypads with the help of metal domes. Underneath each of the keys a metal dome is present, see Figure 3.9.

At a given amount of force and travel when pressing the key, a drop of force occurs and the metal dome depresses. When the metal dome hits the bottom, it notifies the user that the system has recognized the key press, see Figure 3.10. After the user removes his/her finger the key moves back to its originating position.

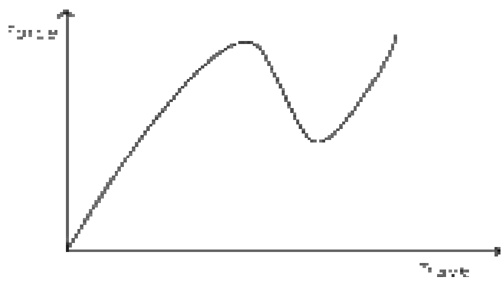


Figure 3.10. The graph shows how the force relates to the travel when pressing a key.

The Table 3.3 presents a comparison of minimum, maximum and recommended force and travel as a result from studies on different input type devices.

Table 3.3 Recommended force and travel.

Source	Input type devices	Force (N) [recommended]	Travel (mm) [recommended]
Handbook of Human-Interaction [12]	Keys and keyboards	0.3-1.4	1.3-6.4
Redefining user input on handheld devices [11]	Handheld devices	1.5-3	-
Bodyspace [4]	Pushbuttons	1.5-9.8 [2.5-3.4]	3-35 [12-15]
The Ergonomics of Workspaces and Machines A Design Manual [2]	Keyboards	1.5-2.9	3-16
Human Factors in Product Design [6]	Keyboards/Keypads	0.3-1.5	-
Human Scale : Hand and Foot Controls [3]	Pushbuttons	1.1-8.9 [1.1-5.6]	1-38 [1-6]

As seen in Table 3.3 recommended force and travel differs. This partly depends on the type of input device investigated and how it is operated. For example, if the keypad is operated while lying on a table or grasped in a special way.

3.1.5 Grip and Form

The way people grasp a handheld device similar to a mobile phone is very relevant to usability because it affects the ability to operate it. One grip could improve the force on which the keys can be pressed, but the same grip might decrease dexterity while operating. Example of factors that have an effect on the grip is width, thickness, length, weight, centre of gravity and surface material of the mobile phone. These values should preferably be chosen in a way that gives the user the best possible experience.

Regarding the recommended width of a mobile phone it can be seen that it depends on which task the user performs. The reference [4] categories two different grips; the power grips and the precision grips. In power grips the fingers and thumb is embracing the object against the palm as seen in Figure 3.11. In precision grips the objects is manipulated between the pads of the fingers and thumb, see Figure 3.12. A standard example of the power grip is when grasping a hammer and an example of the precision grip could be when operating a pen.

Figure 3.11. The power grip

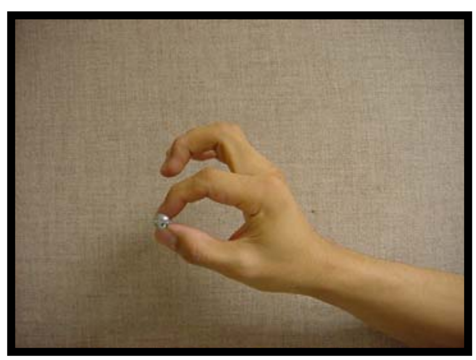


Figure 3.12. The precision grip

When talking, the user's most common grip is very similar to a normal power grip, see chapter 4. It is then possible to recommend the width between 30-50 mm [6]. When writing an SMS the grip is more similar to a precision grip. The recommended width becomes more flexible with that grip, allowing the mobile phone to be either thinner or wider. The flexibility of the thumb now becomes a more limiting factor when recommending the width for writing an SMS.

The thickness of the mobile phone affects the usability in the way that if being too thick it will decrease the flexibility of the thumb. The length of the mobile phone has both minimum and maximum requirements. If the mobile phone does become too long it will be less portable because of size and weight. In opposite, if the mobile phone is too short it will make the handling less accurate.

If the mobile phone weights a lot this will lead to that the user experience more strain after a certain amount of time. According to [7] the weight of a mobile phone should not exceed 280 gram.

Centre of gravity is another important factor regarding the usability of mobile phones. Since people tend to rest the mobile phone close to the fingertips while using it, the centre of gravity should not be located at the top of the mobile phone, see Figure 4.2. Mobile phones feel comfortable to use when having soft rounded edges and a comfortable material that gives enough friction to keep the device from slipping, while resting on the top of the fingers.

3.1.6 Conclusions

As the mobile industry is developing fast most of the guidelines found were old and therefore inadequate today. Following is a summary of the relevant facts that are applicable for mobile phones.

- The horizontal centre to centre distance between keys on keypads should be at least 12 mm.
- The minimal horizontal distance between the keys should be between 3.8-5.6 mm.
- The width of the keys should be at least between 6.5-10 mm.
- The height of the keys should be at least 2.5 mm.

- Keys grouped together with same tasks should have the same appearance.
- Labels on keys should have big font (>10 points) with good contrast.
- Smaller keypads should use convex keys.
- A rocker key with a centre key should be at least 15 mm.
- A rocker key without a centre key should be at least 12 mm.
- When there is not enough space for a rocker key a joystick is a good alternative.
- Tactile feedback on membrane keypads improves keying performance.
- Activation force needed should be between 0.25-2.95 N
- The width of the phone should be between 30-50 mm.
- The mobile phone should not weigh more than 280 g.

3.2 Usability Testing

Usability testing is a method to evaluate products. During usability tests, participants perform tasks under supervision of test monitors (test leaders). An advantage with this approach is that both objective data on how the participants perform certain tasks and personal opinions can be collected. A disadvantage could be that since the participant is performing the tasks in an artificial environment, there is a possibility of obtaining unrealistic results. It is also important to be aware of that the selection of test participants might not always represent the target group for the tested product.

Usability testing is often recorded on video so that people not involved in the test can take part of the results. A standard test setup contains a test monitor, people that log data from the test and people who manage recording devices such as video cameras and microphones. There are also several ways where to conduct usability testing, e.g. in a laboratory or at a workplace.

Depending on the type of test, the monitor could take on several different roles during the usability test, either sitting beside the participant or in an observation room. It is important that the test monitor does not help the participant more than necessary. It could occur that as soon as the participant run into problems, he or she might turn to the test monitor for help. In a real situation the participant would probably tried a little harder before asking someone for help. When the test monitor sits in an observation room the testing environment could be more natural. The user would then be alone while performing the tasks, which would be the case in real life. This could on the other hand lead to that the participant get stressed knowing that he or she is constantly being observed.

4. Pre-study (Field study of grips)

Before it would be possible to determine some recommended dimensions of mobile phones there was need to complete a field study on how the phones are grasped. The field study was performed on thirty people, fifteen men and fifteen women. They were between the ages 18-50 and use their phone on a day to day basis. A standard stick phone with typical dimensions was selected for the test. In the first task, the participants were told to pick up a stick mobile phone and dial an optional number. The result showed four different grips; see Figures 4.1-4.4.

Figure 4.1. Two hand grip.

Figure 4.2. Resting partly on palm.

Figure 4.3. Resting on fingers, supported by pinky tush.

Figure 4.4. Resting on fingers, supported by pinky finger.

Two of the grips were similar, resting the mobile phone on the fingers but with different kinds of support from keeping it sliding. These grips constituted of almost three fourths of the total amount, see Diagram 4.1

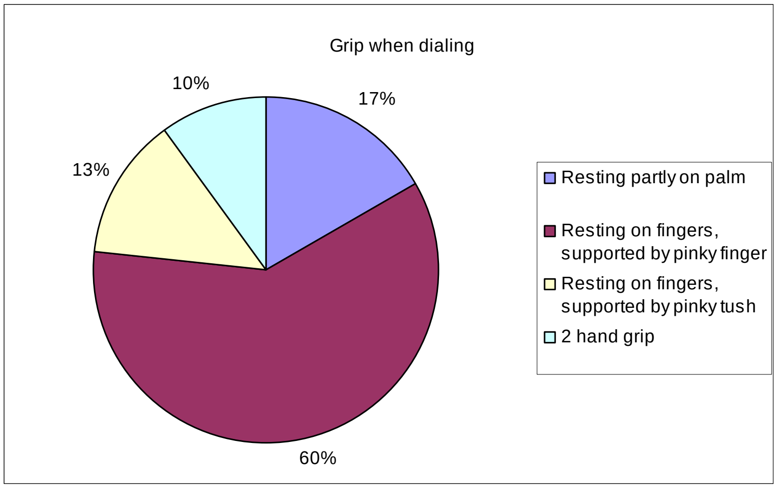


Diagram 4.1. Different grips when dialing.

The second task the participants performed was to pick up the mobile phone and pretend to talk. Participants used three different grips while talking; see figures 4.5-4.7

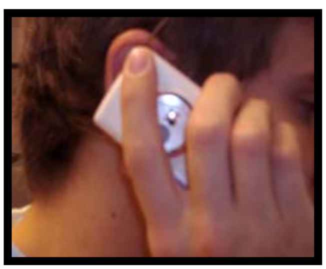


Figure 4.5. 5 finger grip with support finger.

Figure 4.6. 3 finger grip.

Figure 4.7. 5 finger grip, no support finger.

The most common action was grasping the mobile phone with the all of the fingers. Two variants of that grip was observed, either the index finger was diagonally supporting the back side of the mobile phone, see Figure 4.5 , or the index finger just embracing the phone like the other fingers, see Figure 4.6. These grips constituted of more than 90 percent of the total amount, see Diagram 4.2. The third grip found was using just three fingers, but only used by a few participants with big hands, see Diagram 4.2

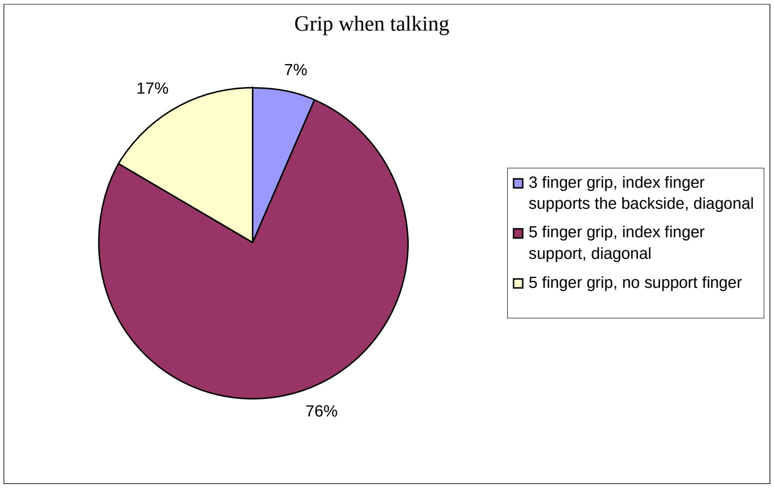


Diagram 4.2. Different grips when talking.

The third and last task performed was writing an SMS. This task showed that most of the participants use the same kind of grip as they did when dialling. The other participants used two hands while operating the phone, see Diagram 4.3.

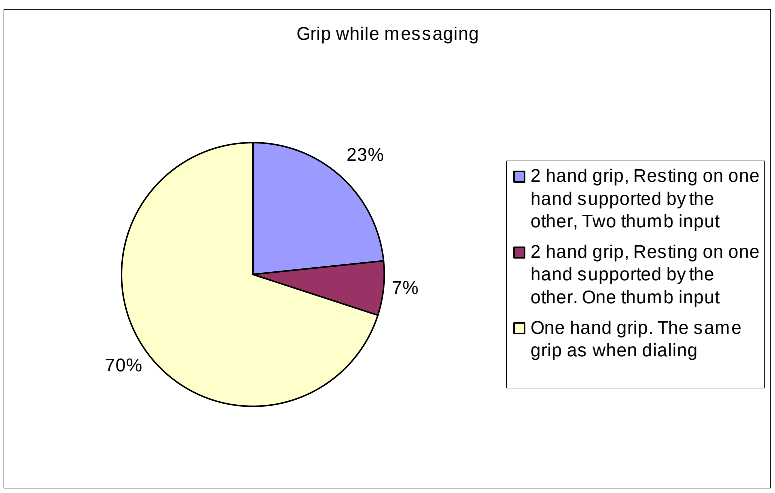


Diagram 4.3. Different grips while messaging.

When comparing the grips while dialling and writing an SMS, it was discovered that users had a tendency to use two hands while messaging. This value would maybe be even bigger if the participants would be told to write longer SMS.

5. Benchmarking

Benchmarks of existing mobile phones were made to find out if there was a conflict between the literature guidelines and existing phones, see Appendix B. Focus of the measurement were factors that could affect the usability of the phone such as; force needed to depress a key, travel of the key, keypad- and the navigation device dimensions. The navigation devices were not always shaped as a circle or a square, and in those cases the vertical dimension was measured because this is the most critical dimension when designing mobile phones. Some conclusions made from the literature research did conflict with some of the results from the measurements on existing phones. For example, all the phones measured had a horizontal distance between keys that were below the recommended value found in the literature research. The Table 5.1 compares the recommended values found in the literature research with the phones that was measured.

Table 5.1. Recommended values from literature study compared to actual measurements. Orange rows shows interesting differences.

Mobile dimensions	Recommended	Measured values		
		Average	Min	Max
Distance between keys (Horizontal)	Min 3.8 - 5.6 mm	0,8	0,0	3
Width of keys	Min 6.5 - 10 mm	10,35	9,0	13
Height of keys	Min 2.5 mm	4,85	2,0	6
Diameter of rocker key	Min 15 mm	14,9	12,5	19
Keys - Force	Min 0.25-2.95 N	2,38	1,3	3,06
Centre to Centre (Horizontal)	Min 12 mm	11,5	9,0	13
Weight of mobile phone	Max 280 g	98,75	77,0	121
Width	30-50 mm	46,25	43,0	52

6. Workshop

After gathering data from the benchmarking of mobile phones, a workshop was conducted to discuss the results and to produce hypotheses. Following describes these hypotheses and how they were established. The hypotheses regarding the keypad and phone dimensions were not further investigated because the lack of time. Pictures of the mobile phones discussed in the hypotheses are presented in chapter 7.4.

6.1 Navigation device

1. **A rocker key with a separate centre selection key can be equal to or wider than 13 mm and still maintain ease of use if properly designed.**

   According to the literature research the diameter of a rocker key should not be less than 15 mm. This value is based on a usability study conducted at Sony Ericsson [9]. After measuring phones it was found that all rocker keys on stick phones (phones that are not foldable) were below the recommended minimum value. The majority of the clamshell phones were on the other hand above the recommended value. The dimension of clamshell phones (phones that can be folded) are not of same interest as stick phones in this thesis, because they do not have the same limited amount of space as a stick phone. Two of the rocker keys measured (Premini II, Nokia N70) both had a diameter of 13 mm and were found easy to use because of their design. A big difference between them was that the Nokia N70 did not have a separate centre key. Instead the whole rocker key had to be depressed for activation.

2. **A small rocker key with a separated CSK gives the user a better feeling of control, compared to pressing the entire key.**

   When comparing the rocker key on the Nokia N70 and the Premini phone it was believed that the rocker key on the Nokia N70 phone had a lack in its control. After a short discussion the conclusion was made that it was because of the lack of a separated CSK it felt that some control was lost. When depressing the whole rocker key it felt wobbly compared to the CSK on the Premini phone which felt more stable.

3. **A rocker key is better to use if properly designed compared to a joystick.**

   According to the literature research the rocker key is preferred over the joystick. The advantage of the joystick is the small space it requires on the mobile phone. During the workshop the conclusion was made that rocker keys are easier and more comfortable to use.

4. **Tactile information on rocker key improves usability.**

   When navigating on a mobile phone the user need to focus on the screen. Even if most users are comfortable with the mapping of the directions, up/down/left and right, small rocker keys can still cause activation of unintentional directions. With the help of tactile information on the rocker key such as adding topography to the rocker key where the user should press (e.g. SE W550). The participants of the workshop believed that this will lead to a decrease in errors.

5. **The surrounding of the joystick affects its performance and a great distance to other keys is good.**

   Some of the joysticks like the ones on the SE K700 and SE J300 were experienced hard to get a hold on because of its surrounding. If keys are put close to the joystick it is easy to accidentally click them and this will cause the user not to fully trust hers/his navigation. Making the surrounding shaped like a crater or similar will make it easier to access the joystick for the user.

6. **A joystick shaped circular with a convex top and an appropriate material providing sufficient friction is more comfortable and easy to use than a joystick shaped concave with sharp edges.**

   Some joysticks investigated had a concave top with sharp edges made out of the same material and some others had a convex top with a rubber top material. In the literature research, it was found that the top should consist of an abrasive material and if it is bigger than 10 mm it should have a concave top. This was confirmed, since the joysticks with concave top and sharp edges felt uncomfortable (e.g. SE K750) after trying them for a while. It is important that the joysticks with convex tops (e.g. W800) have an abrasive top material to prevent the thumb of slipping.

6.2 Keypad hypotheses

1. **Based on ergonomic factors the keypad should be positioned as far up on the phone as possible. However, small differences of only a couple of millimetres can make a huge difference in usability. The distance between the bottom of the phone and the keypad should not be below 8 mm.**

   The thumb is not very flexible when it is bent almost 90 degrees and this affects how far up the keypad should be located. As found in the literature research a precision grip is used when depressing keys on a mobile phone. It is also known that the thumb is more flexible when moving up and down than from side to side. When depressing one of the lowest keys on the mobile phone the thumb is bent the most. This increases the strain and decreases the precision. The participants of the workshop believed that the bottom to keypad distance should not be shorter than 8 mm and only a couple of millimetres increase affect the strain and affect the performance.

2. **The vertical and horizontal centre to centre distances mostly depend on design, but to ensure good ergonomics, 11 mm is a minimum horizontal distance and the vertical distance should be at least 4 mm.**

   The centre to centre distance can be less vertically than horizontally because of ergonomic factors (the precision of the thumb vertically is better than the precision horizontally). However, it's more relevant to look at the vertical distance since larger screens gives the keypad less height if the mobile phone keep its length. The measurement showed a minimum horizontal distance of 9 mm and maximum of 13 mm. The phones with a centre to centre distance of 11mm were easy to use even if findings from the literature research recommended 12 mm.

Vertical measured distances were between 4.5-6 mm. Even if SE J300i (6 mm) has a greater centre to centre distance than SE W800 (5.5 mm) it does not provide better ease of use because of poor key design.

3. **If the activation force needed to press down a key is less than 1.5 N, it is easier to activate surrounding keys unintentionally. If the activation force is more than 3 N, it will cause too much straining for the thumb.**

According to the literature research the recommended activation force should be between 0.25-2.95 N. The measurements showed values from as low as 1.3 N to as much as 4.61 N. The literature research mostly regards keypads, and mobile phones have other limitations. The problem with small keypads is that when you press a key the thumb will rest on more than the intended key, and when pressing the intended key nearby keys will also be exposed to some of the pressure. The conclusion was made that keys with less activation force than 1.5 N (e.g. Premini) will result in too much unintentional activation.

The majority of mobile phones tested required between 2.5-3 N to activate. After testing all of them the most comfortable force would be between 2-2.5 N (e.g. SE T610 and SE J300). Some of the mobile phones needed more than 3 N to activate (e.g. SE J230 and Nokia 6260) and after a short period of testing the thumb became very strained.

4. **"Stairway" keys are easier to manage than flat keys because of the angle of the mobile phone when using the keypad.**

Almost every time a mobile phone is used it is held against the fingers and the palm of the hand. The hand is forming about a 30 degree angle related to the horizontal surface, see Figure 4.2. Because of ergonomic factors the thumb is depressing the keys from straight above. If the keys are flat the thumb will approach and press the keys with an undesired angle. This could be compensated with the help of keys shaped like stairway steps allowing the thumb to press the entire keys from straight above.

5. **If the keys are designed with convex shape, the size of the keypad can be reduced and still maintain ease of use.**

   There are more factors than the size that affects the ease of use. According to the literature research one of the most important factors is making the keys convex. This will increase the effective centre to centre distance. Even if the length of the keypad of the SE K700 is much smaller than many of the phones measured it can still be easier to use than some of them because of the convex shape.

6. **Separating keys and still maintaining the same centre to centre distance only gives a visual difference, no actual improvements.**

   The literature recommends the distance between keys to be 5.6-15 mm depending on the type of keypad and key shape. The measurements showed that these recommendations are not considered when designing the mobile phone because the most common distance between the keys was 1 mm or no distance at all. One mobile phone that showed the most distance was the SE T610 with 3 mm. Comparing and analysing phones with the same centre to centre distance but different distance between buttons lead to the conclusion that the distance will not affect the usability significantly.

7. **The travel distance needed to activate the keys does not affect the overall usability if it's between the average values, 0.13-0.63 mm.**

   The measurements of the mobile phones showed a travel distance between 0.13-0.63 mm with the average of 0.4 mm. The literature research found recommendations between 1.3-38 mm which is not applicable to mobile phones because the literature focused on ordinary, larger push buttons and not on handheld devices. After a comparison of mobile phones with the same force needed to activate the keys, and different travel, it was suggested that if the travel distance is around the average value of the mobile phones it does not have a significant affect on the ease of use.

6.3 Phone dimension hypotheses

1. **The width of the mobile has an upper and lower critical limit (40<x<50). Below or above these values will increase the strain of the hand.**

   In the grip and form section of the literature study two kinds of grips were found to be applicable to the use of a mobile phone, the force- and precision grips. The force grips were the one most similar to the grip while talking. The literature on force grips recommend the width to be between 30-50 mm. From the measurements almost all of the phones were between 40 and 50 mm. This is the value the participants of the workshop would recommend. Some of the phones were more than 50 mm wide (e.g. Nokia N70) which made it uncomfortable to use for users with small hands. The thinnest phone measured was the Samsung S300 with the width of 40 mm. Since people want to embrace the mobile phone against the palm while talking, a phone smaller than 40 mm will require the user to either grasp it and rest the fingers over the keypad or grasping it with only the tip of the fingers. Both of these grips are uncomfortable leading to the conclusion that the width of mobile phones should be between 40-50 mm.

2. **If the mobile phone is so short it can not be grasped with all fingers while talking, the phone is considered too small. The minimum length should be 90 mm.**

   The shortest mobile phone found was 99 mm and was not perceived as too short. After making a quick mock-up prototype it was found that a smaller mobile phone than 90 mm did not feel comfortable to use.

7. Usability Test

This is a test plan used for conducting the usability tests on navigation devices. Following sections are included in the test plan:

- Purpose
- Problem statement
- Test subjects
- Selection of mobile phones
- Description of test-session
- Task list
- Test environment
- Test monitor role
- Explanation of the games
- Performance measures

7.1 Purpose

The purpose of the test was to find factors relevant to the usability on the navigation device of the mobile phones. The tests measured the experienced ease of use and the performance of the navigation device. This was accomplished by ranking the phones and trying to find out what people were thinking throughout the test by applying the think aloud technique. The performance was measured with the assistance of specifically developed games.

7.2 Problem statement

Following are the problems that were addressed in this test and are related to the hypotheses:

Table 7.1. Problem statements.

Navigation Device	Problem statements
General	1. Is a rocker key generally easier to use than a joystick?
Joystick	1. How is the surrounding of the joystick affecting its ease of use? 2. Is a convex joystick with an appropriate material providing sufficient friction more comfortable and easy to use than a concave joystick with sharp edges?
Rocker Key	1. Can diameter on a rocker key with centre key be as small as 13 mm and still maintain ease of use if properly designed? 2. Can a small rocker key with a separated centre key give the user a better feeling of control comparing to a rocker key where you activate the centre key by pressing the entire key? 3. Does tactile information on rocker key improves usability?

7.3 Test subjects

The usability test was conducted in January 2006 and 16 people participated. The users were divided in four equally large categories:

- Inexperienced mobile users aged 18-29
- Inexperienced mobile users aged 30-60
- Experienced mobile users aged 18-29
- Experienced mobile users aged 30-60

The definition of an inexperienced user is one that uses his/hers phone less than 2 times a day and mostly using it for calling. To determine which category every participant belonged to, a questionnaire was developed and carried out by the participants, see Appendix Questionnaire.

7.4 Selection of mobile phones

To give the results from the usability test the best possible conditions the selection of mobile phones was considered carefully. As for the joystick phones five different models were chosen, covering the majority of design solutions. They all have small differences in shape, top area, size and surroundings. See Figure 7.1.

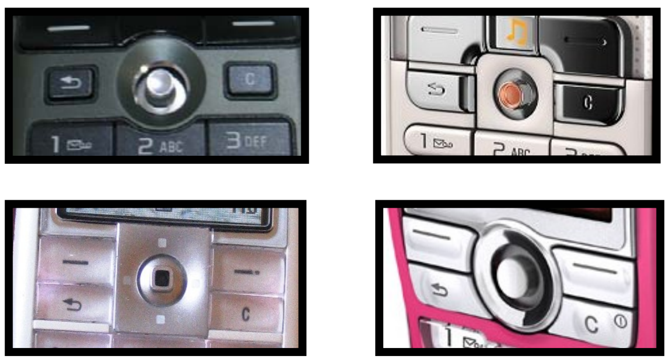


Figure 7.1. Joystick phones that were used in the test. From top left to bottom right: SE K750, SE W800, SE K700, SE T630, SE J300.

The other of the mobile phones has a rocker key as a navigation device. The recommended minimum size when designing small rocker keys with a separated CSK was 15 mm, but 5 mobile phones with less than this minimum size was found. Three mobile phones above 15 mm were also selected. See Figure 7.2.

Figure 7.2. Rocker key phones that were used in the test. From top left to bottom right: Premini-II, SE W550, SE W810, SE J220, Nokia N70, SE Z800, SE Z1010, Nokia 6630.

The rocker keys selected have differences in design, some embossing the edges of the direction key, some adding topography and some with a separated CSK. The rocker keys are also selected so that they easily can be compared to at least one other phone, e.g. the SE Z800 and SE Z1010 where the rocker keys are almost identical, but with the difference that one has dots marking the direction key, see Figure 7.3. This will make it easier to determine factors that affect the usability.

Figure 7.3. The SE Z1010 and the SE Z800.

7.5 Description of test-session

Following section aim to present how the test was performed.

7.5.1 Welcome and questionnaire

The participant was met and welcomed in the main lobby by the test monitor. After the welcome the participant was shown to a room where he/she filled out a questionnaire about the participants' background information such as age, sex, experience of mobile phone etc. A photo was taken of the user and the users' current mobile phone as a reference.

7.5.2 Briefing

The participant was briefed about the tests purpose and how it was going to be carried out. The participant was told that the test was being videotaped and that it was the product that was going to be tested, not the participant. The test monitor did also say that he is not a designer of the product to make the participants more comfortable criticizing the mobile phones.

7.5.3 The Test

The participant performed different tasks and the test monitor took notes regarding the performance of the participant. The users ranked the mobile phones after their ease of use. Ease of use is defined in this test as: "The navigation device is reacting the way the user expects it to react, providing the users finger a comfortable feeling and performs the task with maximum efficiency". During the test two games was used, called jMaze and jNav. They are explained in detail at the end of the test plan.

The test was divided in two different sections. In the first section the users played the jMaze game on every mobile phone and ranked them individually. Half of the users tried the rocker key phones first and the other half tried the joystick phones first. Even the order of mobile phones within the navigation groups (joystick and rocker keys) was randomized to eliminate possible learning effects[3]. One way to test different kind of navigation solutions could be to use the same mobile phone and just replace the navigation keys. But since this was not practically possible the mobile phones for this test was carefully selected so that almost only one factor is different between certain phones. This was done to more accurate come to a decision what was making a navigation device good or bad. In the second section of the test, the user played another game called jNav. In opposite of the first game, the user navigated when holding the mobile phone under the table. After the test of each mobile phone was completed, the user ranked the mobile phone before picking it up from under the table. The test monitor also asked if the user felt secure that he or she had reached the final destination. This was to enhance the importance of activity feedback. There are also occurrences when the user wants to navigate through the menu without looking. Example of this could be when driving and trying to call. This would preferably be accomplished looking at the screen as little as possible, making it crucial for the user to feel that the navigation device has a good control.

[3] Learning effects will arise if the same task is performed over and over again. After completing the same task several times the participant will improve his/hers performance.

7.6 Task list

Table 7.2. Task list. SCC meaning successful completion criteria and MTC meaning maximum time to complete.

Task no.	Task description	Task detail
1	Joystick : jMaze	**Task:** Navigate your way through the game on the different mobile phones using only the joystick. When you move over the small dots press the joystick before continuing. When you have reached the goal the test monitor will ask you to rank the phone according to its ease of use. The test monitor will hand you the next phone when you are finished. **Requirements:** Joystick phones. **SCC:** User navigates through the maze. **MTC:** 5 min per mobile phone.
2	Rocker key : jMaze	**Task:** Navigate your way through the game on the different mobile phones using only the rocker key. When you move over the small dots press the CSK before continuing. When you have reached the goal the test monitor will ask you to rank the phone according to its ease of use. The test monitor will hand you the next phone when you are finished. **Requirements:** Rocker key phones. **SCC:** User navigates through the maze. **MTC:** 5 min per mobile phone.
3	Joystick : jNav	**Task:** You will be given a set of mobile phones and a paper showing a grid with three different circles. Hold the phone under the table and navigate to every circle in the grid. When on top of a circle press the joystick before continuing.

		After you have reached the last circle, please rank the phone according to its ease of use. Before looking at the result of the game, please tell the test monitor if you feel secure that you actually are standing on the last circle. **Requirements:** Joystick phones. **SCC:** User reaches the last circle. **MTC:** 5 min per mobile phone.
4	Rocker key : jNav	**Task:** You will be given a set of mobile phones and a paper showing a grid with three different circles. Hold the phone under the table and navigate to every circle in the grid. When on top of a circle press the CSK before continuing. After you have reached the last circle, please rank the phone according to its ease of use. Before looking at the result of the game, please tell the test monitor if you feel secure that you actually are standing on the last circle. **Requirements:** Rocker key phones. **SCC:** User reaches the last circle. **MTC:** 5 min per mobile phone.

7.7 Test environment / Equipment

The usability test was conducted with a setup called "Electronic Observation Room Setup" [17]. This is a two room setup with hidden observers in one of the room and the test participant is sitting in another room guided by the test monitor. The participant was recorded using video cameras. Theses cameras were aimed towards the table where the participant was operating and towards his/her thumb. The purpose was to capture how the participant ranked the mobile phones and how he/she used the navigation device. The voice was recorded by using microphones.

7.8 Test monitor role

The test monitor guided the participant through the tasks when sitting right next to her/him. The test monitor asked questions and tried to make the user feel comfortable. When the user ranked similar phones differently, the monitor asked the user to describe them and explain why one of them is better. This was performed to more easily understand what makes the navigation devices good or bad.

7.9 Explanation of the games

Two games were developed in J2ME (Java Micro Edition) to measure how the participants actually are performing while navigating with the different mobile phones. The advantage of this approach is that the users tried the same game on all of the phones and did not get influenced by the different menu systems.

7.9.1 jMaze

In jMaze the participants navigated through a maze with the help of the navigation device, see Figure 7.4. There is only one way to navigate, and if the user accidentally presses the wrong direction this was recorded and presented along with the time when the maze was finished. To include the usage of the CSK, there are dots that need to be pressed through out the maze.

Figure 7.4. jMaze game

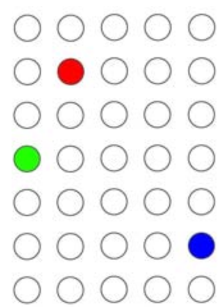


Figure 7.5. jNav game.

7.9.2 jNav

In this game the users navigated without looking at the screen or navigation device. Instead they tried to navigate with the help of instructions on a letter, which had the exact same appearance as in the game. The users started at the green circle and navigated to the red circle where they were told to press the CSK. After this they navigated to the blue circle which was the goal. After they were finished they could look at the screen and see if they reached the goal, see Figure 7.5.

7.10 Performance measures

Following presents the subjective and objective data that was collected during the usability test.

7.10.1 Subjective measurements

A User Compass Chart (UCC) [16] was used as an aid when ranking the mobile phones. The UCC is a compass chart with two vectors describing two properties. The compass chart is divided into four sections, a good and a bad side of each property. The most desirable section of the UCC is for that reason the north-east which is a combination of the best from the both assigned properties. The participant was told to rank every object by placing it onto the UCC resulting in a complete ranking of every object, see Figure 7.6. The participants were allowed to move around the objects if they changed their opinion during the test. It became natural for the participant to motivate why placing every object in the specific position because of the vectors and the possibility to compare the objects. This gave many important subjective opinions during the test.

Figure 7.6. User Compass Chart (UCC)

The properties for the UCC were defined in this test *experienced control* and *experienced comfort*. These were chosen to support the definition of ease of use in this thesis. The users were told that the definition of control is if “he/she feels that the navigation key does exactly what he/she wants it to do”. An example of a bad control could be if the navigation key goes to another direction than the user pressed, or if the users get the feeling that an activation of a key results in an activation of several keys at the same time. Comfort was defined as how comfortable the user thinks the navigation key feels for the thumb. An example of bad comfort could be if the user thinks that the navigation key is too hard or too easy to activate, or if an edge is too sharp.

7.10.2 Objective measurements

Following objective data was collected:

- Accidentally pressing the wrong direction when the participants were going through the maze.
- Time it took to complete the task when navigating through the maze.
- End position from the jNav game to see if the users have reached the goal.

8. Discussion of usability test

The selection of the participants for the usability test was based on their age and experience using mobile phones. It was nevertheless important to know what kind of mobile phone the participants had and if they preferred joysticks or rocker keys as navigation devices. When analyzing data from the background questionnaire and interviews, half of the participants had a mobile phone with a joystick and the other half a mobile phone with a rocker key.

It was quite clear during the test that even if most users had one kind of navigation device they did not favor that one when grading the mobile phones. One risk with the approach of letting the users grade the mobile phones was that some users would place all phones very close to each other in the UCC, either thinking that the navigation devices were all good or all bad. Since almost all participants experienced a big difference between the navigation devices considering control and comfort, they used the entire UCC when ranking the mobile phones.

The monitor allowed the participant to change the ranking of the phones because some users had difficulties grading the mobile phones in the beginning of the test. After trying some different design solutions the participant could relate to the other mobile phones and more easily rank them.

When looking at the grading of the mobile phones, about half of the phones were ranked very differently during the tests, the other mobile phones were rated quite similar, e.g. the SE W550 almost always got top grades, followed by phones such as the SE W800 and Premini. Mobile phones like the Nokia N70 and the SE J220 got bad grades from the majority of participants.

One of the mobile phones turned out to be defective showing more errors than the user actually made and this one was quickly replaced with a working one. Another problem was two phones not equipped with java making it impossible to play the games. Since these mobile phones had an interesting design of the navigation device they were included anyway, leaving out objective data. The participants were told to navigate in the menus of the two phones, pretending it was a maze similar to the other mobile phones. They had no problems giving grades because of this issue. At the end of the usability test, the participants were asked if they would replace the navigation device on their on mobile phones with any of the tested navigation devices. Almost everyone said they would do this, if possible, implying that they were not that satisfied with their present one. The most appreciated navigation device was the one from the SE W550, Premini-II or the SE W800.

8.1 Limitations of usability testing

It is important to be aware of limitations when evaluating products so no rash conclusions are made. In this masters thesis the following limitations regarding the usability testing have been identified.

8.1.1 Selection of mobile phones

Thirteen mobile phones were used in the usability test. These phones were chosen to represent the different kinds of navigation devices available today, either using a joystick or a rocker key. The mobile phones might not reflect all different design solutions but it would not be possible to test all phones. The selection was nevertheless carefully made to represent the majority of design solutions.

8.1.2 Isolation of factors

When it comes to analyzing the usability test a problem is the isolation of factors. If a comparison between phones is done, and one of them outperforms the other, the difficulty is to determine the significant factors. That is why the phones being compared have been chosen so they have the least possible factors separating them apart. A better solution would be to design one mobile phone and just change one factor; size, shape and force etc. This is not possible to accomplish within the time and budget for this thesis work.

8.1.3 Selection of participants in the usability test

A common problem when conduction usability tests are that the users not always represent the entire target group of a product. The participants for this usability test were chosen carefully so that they are representing the target group in the best possible way. They were divided in four different groups, depending on both age and mobile skills.

8.1.4 Measuring data

One way of testing the navigation device on mobile phones would be to let the user navigate through each menu of every phone. But if that was the solution one major problem is that the participant would be influenced differently by the software of the phones, which would affect the ranking of the phones. This is not wanted since it is the navigation device to be tested, not the software of the mobile phone. A solution to this problem could be to turn off the displays on every phone. In this case a new problem would arise; turning off the display would also mean turning off the visual feedback for the participant. In this master thesis a new approach was developed, the jMaze game. Because this is developed in java, the game looks and performs equally on all mobile phones. With this solution the two problems with different software on different mobile phones and loosing visual feedback are solved. However, there is one minor issue with this approach. Is the navigation in the maze equal to navigating in a menu system of a mobile phone? Since the menu systems are different on every mobile phone it would be hard to answer, and the focus of this thesis is the usability of the navigation devices.

9. Results

Each test person rated the navigation devices after their control and comfort in the User Compass Chart. Its two crossing vectors was divided into a scale reaching from one to five, see Diagram 9.2. Diagram 9.1 shows the average grade each phone got including its standard deviation.

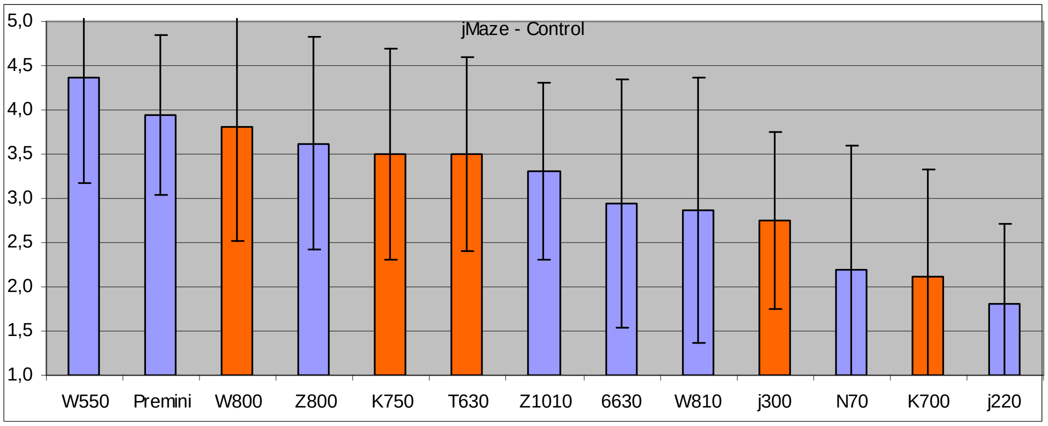
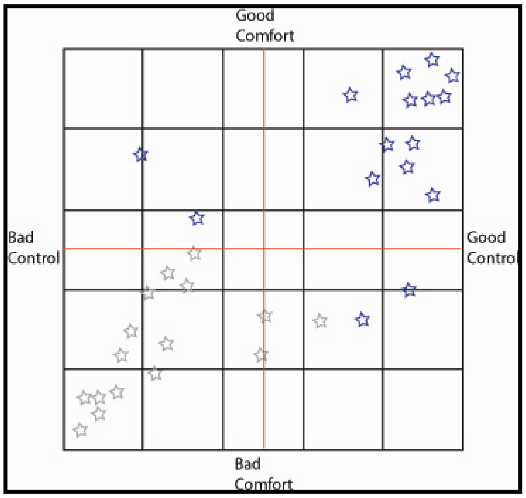


Diagram 9.1. Experienced control. Average result of how the users (N=16) graded control after jMaze. Orange bars are joystick phones and blue bars are mobile phones with a rocker key and the thin bar is showing its standard deviation.

The diagram shows that the SE W550 was experienced as having the most control and its rocker key is one of the larger navigation devices used in the test. The Premini on the other hand had one of the smallest rocker keys used in the test and it was graded as the second best outperforming several large rocker keys, this excludes the theory “bigger is better”. In the diagram it can also be seen that the SE W800 is rated as the best joystick phone in control. The user comments tell that it is distinct and has a good tactile feedback. The Diagrams 9.2, a and b, down below is showing the actual user ranking for some of the phones. The ranking of SE W550 and SE J220 is illustrated in diagram a to show that those phones got a very different but clear result compared to the ranking of SE Z800 and SE Z1010, where it is hard to say which one that is the best.



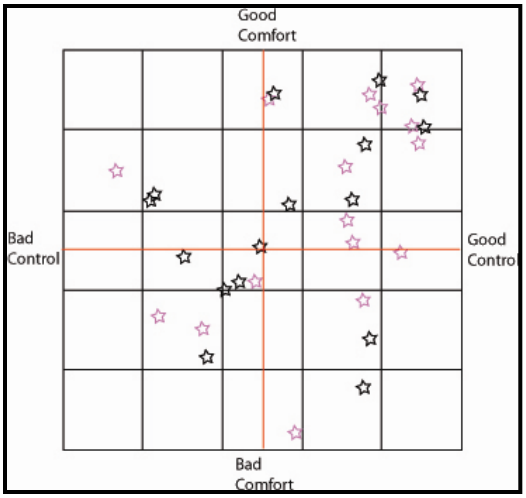


Diagram 9.2 a and b. Scatter diagram over subjective ranking (N=16). Left (a): blue is ranking of SE W550 and grey is ranking of SE J220. Right (b): black is ranking of SE Z1010 and purple is the ranking of the SE Z800.

Phones ranked very well or bad had a low deviation as seen in the left grid and phones that got an average grade had greater deviation.

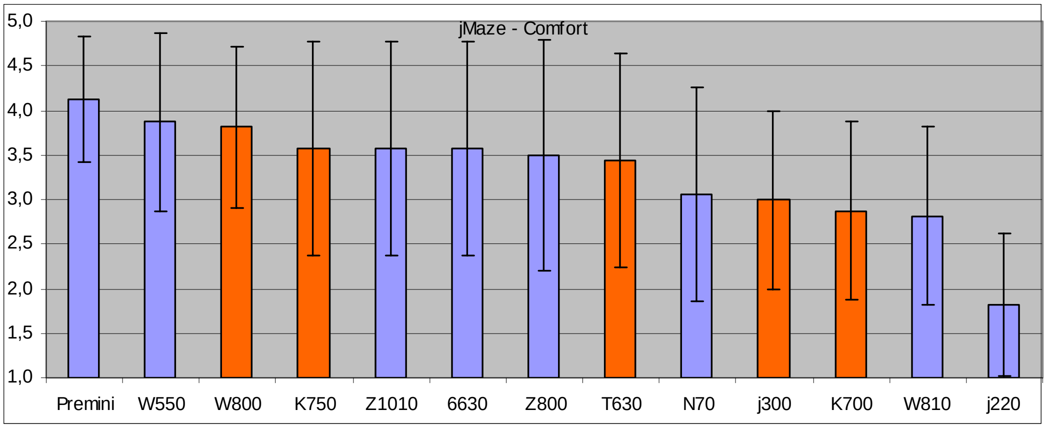


Diagram 9.3. Experienced control. Average result of how the users (N=16) graded comfort after jMaze. Orange bars are joystick phones and blue bars are mobile phones with a rocker key and the thin bar is showing its standard deviation.

The result in comfort, see Diagram 9.3, does not significantly differ from the results in control and there was a low correlation between the two which indicates that the participants had difficulties to separate control and comfort.

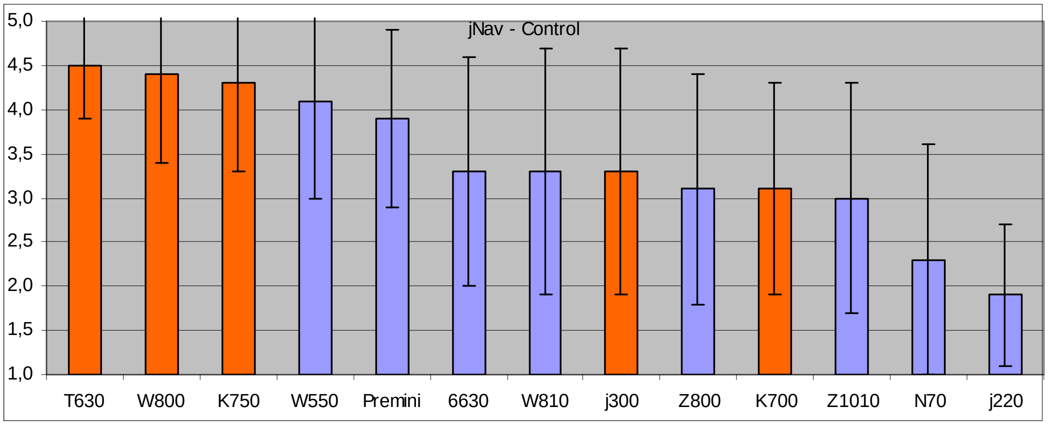


Diagram 9.4. Experienced comfort. Average result of how the users (N=16) graded control after jNav. Orange bars are joystick phones and blue bars are mobile phones with a rocker key

The result from the jNav test, see Diagram 9.4, shows that the top three phones use a joystick for navigation. A more thorough discussion of why the three joystick phones were top rated during this test is explained in chapter 11 (Conclusions).

After playing jNav the users were asked if they were sure that they were on the right spot. Table 9.1 shows if the participant was sure if he/she had reached the final destination, and at the same time if the participant was correct. A good example is the SE T630, because all the users knew if the phone reached the final destination or not. Because the Premini and the J220 was not compatible with Java there could not be shown if the user actual ended up on the right spot, but the chart indicates that the rocker key on the J220 has poor design.

Table 9.1. Objective and subjective results for jNav. Describing if test persons (N=16) were sure if they were at the right spot and if they actual where right.

jNav Results							
	K750	**K700**	**J300**	**W800**	**W810**	**Z1010**	**W550**
User unsure, jNav wrong	4	0	2	3	0	2	1
User unsure, jNav right	0	9	7	1	7	4	1
User sure, jNav wrong	1	2	4	0	2	2	3
User sure, jNav right	10	4	2	11	6	7	10
	T630	**Z800**	**N70**	**6630**		**Premini**	**J220**
User unsure, jNav wrong	3	1	2	3	**User unsure**	3	16
User unsure, jNav right	0	4	2	3	**User sure**	13	0
User sure, jNav wrong	0	4	8	7			
User sure, jNav right	12	6	3	2			

To demonstrate the objective data collected, all the values were first standardized to eliminate the differences between each participant's performances. Standardizing gives a value that competes with only the users' average performance and is not affected by other participants. For example, a user A makes an average of 10 errors and makes 13 errors on one of the phones P. Another user B makes an average of 2 errors, but makes 5 errors on phone P. Both of the test persons makes 3 errors above their average value on the same phone, but it is more crucial for user B because he/she performs better in average. This might depend on that B could be more experienced of using mobile phones and by making standardization this problem will be reduced. The standardized results over time and error rate are shown in the following diagram where negative values are representing time and error below average performance.

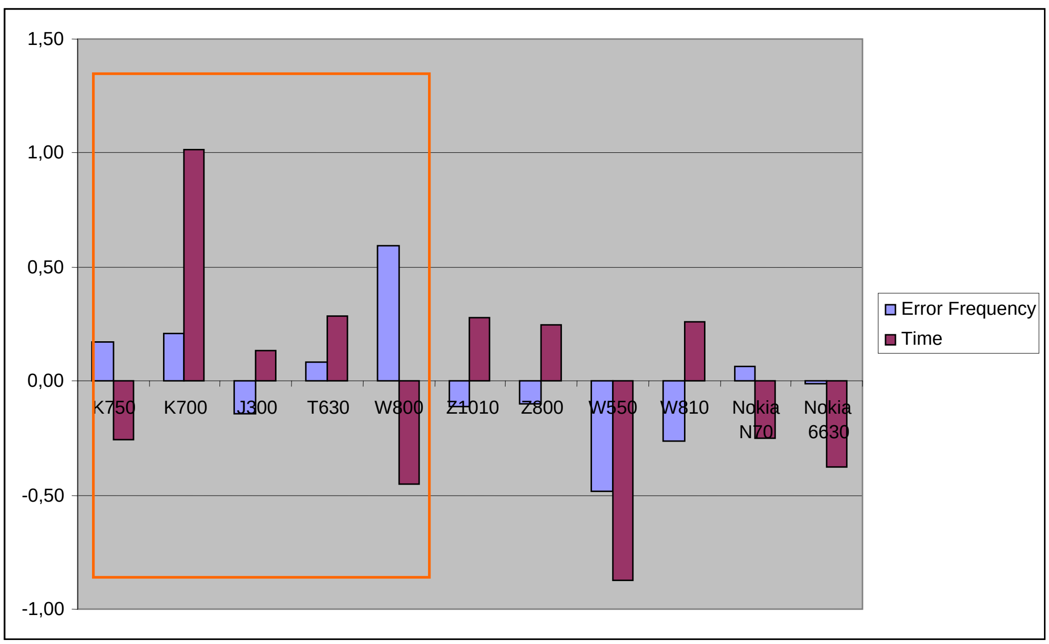


Diagram 9.5. Objective data. Standardized values from jMaze for each phones. Negative values are showed if the phones performed well. Phones inside the orange square use joystick as a navigation device.

As seen the two Nokia phones did perform well but when looking at the subjective data where the test persons got to rate the phones the two was not very popular. This conflict might depend on that the user did not feel secure using the phones, and as found during the workshop this could depend on the lack of a separate CSK. The SE W550 outperformed all other phones in both error made and time to complete the maze.

10. Statistic analysis

The statistical evaluation was performed in three different steps using a statistical analysis program called SPSS. The first step was to compare the data such as time, errors, thumb size and age etc. This was conducted with either an ANOVA or Mann-Whitney test depending on the data compared. In the next step a Pearson correlation was made to see if there was correlation between the subjective or objective data from the usability test (e.g. error, time compared to control and comfort) and the measurements made (e.g. activation force, click ratio and travel etc.). The third step was to perform an ANOVA test comparing the users ranking of phones, time and errors with the mobile phones too see if there was a significant difference between the performances of the different mobile phones.

10.1 Comparisons

Following are the significant findings from the statistical analysis and further explanations are discussed in chapter 11.

- There is no difference in error and time between joystick and rocker keys.
- Joysticks have more control when navigating heads up (without looking at the screen).
- There is a difference in error and time between age groups. Age group 18 to 29 years old people tend to make fewer errors and navigate faster throughout the test than the participants between 30-60 years old.
- There is no difference between age group and their ranking of mobile phones.
- People that have a thumb size less than 18 mm tend to do fewer errors than people with a thumb size of 18 mm or above.
- People with a thumb size of 18 mm or above tend to rank the navigation keys lower in comfort.
- People that are more experienced using their mobile phone make fewer errors and perform the test faster than people with less experience.

- There is no difference in ranking the phones in control and comfort between experienced and less experienced people.

10.2 Correlations

The correlation coefficient, *r*, from a Pearson correlation tells the degree to which two variables are related. If there is a perfect linear relationship between two values, r is 1 if it is a positive or -1 if it is a negative relationship. In this thesis a positive or negative r value of 0.4-0.8 is considered as low correlated. Values below -0.8 and above 0.8 are considered as highly correlated. Very few correlations were found and those found were only correlated at a low level.

Table 10.1 The Table shows the correlations coefficient between data from usability test and benchmarking study. Orange cells show correlations found (only at low level)

		jMaze		jNav		jMaze	
		Experienced Control	Experienced Comfort	Experienced Control	Experienced Comfort	Errors	Time
jMaze	Errors	-0,28	-0,02	0,05	0,03	1	0.40
	Time	-0,25	-0,11	-0,24	-0,16	0.40	1
Centre Selection Key/Joystick	Force	-0,20	-0,08	-0,28	-0,08	-0,02	-0,09
	Travel	0,17	0,14	0,34	0,17	0,04	0,08
	Click Ratio	0,28	0,21	0,36	0,22	0,05	0,05
Direction Key	Force	-0,29	-0,42	-0,28	-0,35	0,03	0,15
	Travel	0,49	0,41	0,35	0,30	-0,01	0,03
	Click Ratio	0,53	0,47	0,43	0,38	0,04	-0,07

10.3 Comparison between mobile phones

The comparison between the mobile phones found several significant differences, and if more users would be tested it is likely that more significance would be found. When looking at the objective data there was almost no significance between the mobile phones, the only one found is that the SE W800 is significant faster than the SE K700. The orange color means comparison between mobile phones with joystick as a navigation device. Blue color means comparison between mobile phones with rocker keys.

Time jMaze

- W800 is significant faster than K700 during jMaze

Experienced Control - jMaze

- K750 is ranked with significant better control than J220
- W800 is ranked with significant better control than J220
- T630 is ranked with significant better control than J220
- W550 is ranked with significant better control than K700
- W550 is ranked with significant better control than J300
- W550 is ranked with significant better control than N70
- W550 is ranked with significant better control than J220
- Z1010 is ranked with significant better control than J220
- Z800 is ranked with significant better control than J220
- Premini is ranked with significant better control than K700
- Premini is ranked with significant better control than N70
- Premini is ranked with significant better control than J220

Experienced Comfort - jMaze

- K750 is ranked with significant better comfort than J220
- W800 is ranked with significant better comfort than J220
- T630 is ranked with significant better comfort than J220
- W550 is ranked with significant better comfort than J220
- Premini is ranked with significant better comfort than K700
- Premini is ranked with significant better comfort than J300
- Premini is ranked with significant better comfort than W810
- Premini is ranked with significant better comfort than J220
- Z1010 is ranked with significant better comfort than J220
- 6630 is ranked with significant better comfort than J220

Experienced Control - jNav

- K750 is ranked with significant better control than N70
- K750 is ranked with significant better control than J220
- T630 is ranked with significant better control than K700
- W800 is ranked with significant better control than N70
- W800 is ranked with significant better control than J220
- T630 is ranked with significant better control than N70
- T630 is ranked with significant better control than J220
- W550 is ranked with significant better control than N70
- W550 is ranked with significant better control than J220
- Premini is ranked with significant better control than N70
- Premini is ranked with significant better control than J220

Experienced Comfort - jNav

- K750 is ranked with significant better comfort than J220
- W800 is ranked with significant better comfort than J220

- T630 is ranked with significant better comfort than J220
- W550 is ranked with significant better comfort than J220
- W810 is ranked with significant better comfort than J220
- Z1010 is ranked with significant better comfort than J220
- 6630 is ranked with significant better comfort than J220

11. Conclusions

The experience from the usability test, the benchmarking and the literature research was used to solve the problem statements and hypotheses and the following present the answers. Problem statements and hypotheses are related to the following questions.

11.1 General

1. **What are the general differences in navigation between a rocker key and a joystick?**

   There are two different ways of navigating where the user either can let go of the navigation device every time he/she wants to change direction or to keep the thumb onto the navigation device throughout the whole navigation session. People tend to let go of the rocker key when changing the direction except in a couple of cases where the participant kept their thumb onto the rocker key. When people used a joystick phone, half of the test persons kept their thumb onto the joystick while the other half tend to let go of it when navigating.

   Another observation was that the users had a change of opinion in the jNav test where three of the joystick phones (SE T630, SE W800 and SE K750) got the highest grades instead of the Premini and SE W550 which was top ranked in the jMaze test. The objective data received from the jNav test supports the user ranking because most users reached the final destination, see Table 9.1. The joystick was significant better in experienced control when navigating heads up. There was no statistical difference between rocker key and joystick when navigating while looking at the display.

   An explanation to why the joystick is better when navigation heads up might be that when the user wants to go to a direction it might feel more natural to move a joystick towards the same direction instead of just depressing a key downward. It could also depend on that the joystick moves sideways providing more kinesthetic feedback than with a rocker key.

2. Why is some navigation devices experienced easy, hard and distinct to press?

There are different factors that affects why the participants felt that some navigation devices were easy, hard and distinct to press. They are identified as shape of the navigation device, click ratio, travel and force needed to depress the key.

When looking at the comments from the participants it is shown that they experience the SE T630 joystick hard to depress, which was not experienced with the other joystick phones. This is interesting because according to the measured force needed to depress the joystick, they were all very similar, see Table 11.1.

Table 11.1. Measured values for joystick phones.

	K700	K750	J300	W800	T630
Force (N)	1.41	1.5	1.42	1.53	1.46
Click ratio	0.53	0.53	0.5	0.6	0.41
Travel (mm)	0.09	0.09	0.09	0.08	0.08

The click ratio (defined as the max force needed right before dome collapses minus the force needed when the dome hits the bottom divided by the max force) are all pretty similar as well. The distance in travel between the phones is very short which makes it almost impossible to feel the difference. The most considerable difference between the joystick phones are the design and not the mechanics. Because SE T630 has corners one theory is that the corners is pressed into the thumb and this feels uncomfortable and therefore experienced hard to press. This theory was confirmed by some of the users that complained about the sharp corners.

When considering rocker keys, people experienced some of the phones indistinct (SE J220, SE W810, Nokia N70 and Nokia 6630). All of them have a very low click ratio compared to the phones that were described as distinct (SE W550, SE Z800 and Premini).

Table 11.2. Measured values for rocker key phones.

		J220	W810	W550	Z800	Premini	Nokia N70	Nokia 6630
CSK	**Force (N)**	2.48	2.44	1.91	2	1.21	3.77	4.73
	Click ratio	0.14	0.12	0.43	0.45	0.42	0.07	0.10
Direction key	**Force (N)**	3.37	2.38	2.28	2.2	1.25	2.07	1.98
	Click ratio	0.08	0.17	0.35	0.29	0.35	0.14	0.16

There was a relation between the click ratio and what users experienced distinct. If the click ratio is very low (<0.17) users experienced the navigation device to be indistinct, but if the click ratio is higher (>0.30) users experienced them as distinct. No upper limit of the click ratio has been found because the phone with the highest click ratio was experienced distinct.

The Premini phone has a low force needed to depress the rocker key (1.21 N) compared to the rest of the rocker key phones. The force needed to depress the dome on the Nokia 6630 is very high (4.73 N), but there was no comment that it was hard to depress. This might depend on its shape. Because it fits the thumb the force is divided on a bigger area of the thumb compared to the SE W810 phone where only the tip of the thumb is used. The Premini phone was experienced soft to depress in a good way and this might be because of the low force needed to depress. According to the literature research this value should be between 0.25 and 2.95 N and the force of the Premini phone is almost in the middle of this value, but this does not mean that it is an optimal force. Other factors such as shape also need to be considered. The Premini had the lowest force and therefore a lower limit could not be tested.

3. Is there a relation between size of thumb and results?

Thumb size was divided into two groups. One group with a thumb size below 18 mm (distance between one side of the tip of the thumb to the other side) and the other group with a thumb size of 18 mm or above. There was a significant difference in errors made between the two groups, where the group with small thumbs did fewer errors. Because there were a small number of participants there might be a risk that other factors like age and mobile experience affects this result, but after running statistical tests comparing the factors it was found that the thumb size was the most significant factor (see Table 11.3). The conclusion to be drawn is that if the user has a smaller thumb it might be easier to get hold of the navigation device and is not affected by the surroundings as much as the people with larger thumbs.

Table 11.3. Results from a statistical test. How user errors are affected by different sources. The smaller number, the more significant.

Source	Sig.
Age	0,003
Thumb size	0,000

Source	Sig.
Mobile experience	0,361
Thumb size	0,001

4. Is there a relation between age and results?

It is significant difference that people who is 30 years old or above tends to make more errors and need more time to navigate through the maze than younger people. An explanation to this might be that older people have less dexterity in their thumbs. This is important to consider when designing easy to use phones to that target group.

11.2 Rocker keys

1. Does the size of the rocker key affect its ease of use?

A general opinion about rocker keys is that if it lack in control making it bigger would solve these issues. According to the literature research, 15 mm was the limit when designing rocker keys. During the test, four rocker keys with a diameter of less than 15 mm were tested. It was discovered during the test that these different rocker keys all performed very differently, giving the conclusion that there are more relevant factors than the size when deciding if a rocker key is easy to use. One of the smallest rocker keys, the Premini-II with a diameter of 13 mm, was actually graded as the second best in control comparing with all of the other navigation devices (including joysticks and rocker keys). Also, when looking at the objective data received from jMaze some of the small rocker keys performed better both error- and time wise compared to some of the larger rocker keys. A rocker key could be at least 13 mm in diameter and still maintain ease of use if designed properly, and perhaps even smaller. This could not be tested because there were no usable rocker keys less than 13 to be found. Designing a small rocker key requires a lot more effort to make it easy to use compared to designing a big rocker key because it is harder to separate the keys. This will make it easier to accidentally depress more than one key at the same time. The problem can be avoided by enhancing the tactile information. Some small rocker keys provided bad ease of use. An example of this is the SE J220 which was graded as the navigation device with the worst control, mainly because its design does not provide enough separation between the CSK and direction key.

Looking at both subjective and objective data from the test, a big rocker key is generally not better than a small one. The factor that primary affects the usability is the design of the key and not the size of it. According to comments made by test persons embossing of the direction key, tactile feedback, separation between the CSK and the direction key are the most affecting factors of the usability. This test has shown that the lower limit can be as low as 13 mm for a rocker key with a separate CSK if it is designed well. What makes up for a good design will be discussed in the following section.

2. How is the navigation affected by enhancement of the tactile information?

Regular comments were made by the test participants about what they liked or disliked by the tactile information on the keys. Therefore, it was probably a contributing factor when grading the navigation device.

Two of the larger Sony Ericsson mobile phones are very similar (SE Z800 and SE Z1010), but with one major difference. The SE Z1010 has small dots at its direction keys compared to SE Z800 which only has a visual guidance with small arrows. The intentions of the designer were probably that the dots would help the user finding where to press. The users' opinions were not consistent, some of them said that the dots helped them finding the way, but the same number of users said the dots were confusing. When looking at the subjective data from the grading of the two mobile phones, the SE Z800 got a slightly better grade after both jMaze and jNav. When the users played jNav they did not look at the rocker key, and if the dots would help them, SE Z1010s results would most likely be better than SE Z800, but this was not the case. The objective data from jMaze showed no difference between the two mobile phones. Same results were achieved from the heads up test, with no significant difference between the phones. According to this test there is no difference in ease of use using dots to help the user navigating. The literature research implies that this should improve the control. A probable explanation could be that, in alignment with the user opinions, since the middle button of the rocker key is very similar to the helping dots, the user has trouble knowing if the thumb is resting on the middle button or one of the direction dots. A more distinct difference between the CSK and the directions could help the navigation and improve the control.

The SE W550i was graded as the best rocker key in both jMaze and jNav and also got very positive comments. If comparing it with the SE Z1010, it also has tried to enhance the tactile information. Instead of adding dots it has topography on each direction, different material between the CSK and the direction key, which makes it easier for the user to feel where the thumb is resting and therefore improving the control when navigating.

Two of the small rocker keys, the Premini-II and the SE W810, are similar in design, both round and with a separate CSK key. The main difference when comparing is that the direction key is embossed on the Premini and flat on the W810. According to the users they experienced that it was difficult to feel where to press on the W810 because it was flat, and therefore no distinct separation between the CSK and the direction key. The users experienced it more easily to feel where to press on Premini because of its embossed direction key and significant separation between the CSK and the direction key.

The rocker key that received the worst grade by the user was the SE J220. Instead of embossing the whole direction key like the Premini or the W550i, the rocker key on SE J220 has embossed the outer edges of the direction key. According to the user opinions this helps the user to know where the thumb should press, but since the edges are so thin, combined with high force needed to press the keys, the feeling of comfort is considerable reduced.

3. How is the navigation affected by the different CSK solutions?

Two of the eight rocker keys used in the usability test do not have a separate CSK and to activate the centre key the user had to press in the middle of the rocker key. The other rocker keys have separated the CSK from the direction key.

The first thing to be analyzed is how a rocker key with a non separate CSK, such as Nokia N70 and 6630, affects the control or comfort. The user ranking after playing jMaze shows that the control is ranked below the average for both phones. The only value that has a considerable difference from the other rocker keys is the time needed to complete jMaze. In this test both mobile phones were faster than the average. One factor affecting the time could be that the users do not have to move their thumbs as much depending on its size and that it is easier to slide the thumb across the rocker key, instead of lifting it and placing it on the different positions. Some of the users say that they feel when pressing the CSK that some of the direction keys are activated at the same time. This could explain why the grades are poor in control. However, according to the objective data users do not make more errors with the two Nokia phones than the average phone.

A considerable difference between the two Nokia phones is that on the Nokia N70, the middle of the navigation key has an imitation of a key. Comparing the results between the two phones shows that Nokia N70 is slower and makes more errors. The user opinions imply that the imitation key on the Nokia N70 is hard to feel. The rocker key on the Nokia 6630 got a higher grade in comfort and the user comments imply that it is because the thumb fits into the concave key. This gives the conclusion that if a rocker key does not have a separated CSK it could be better to make it concave instead of adding an imitation of a key.

The rocker key of the Premini is very similar to the Nokia 6630 and the most considerable difference is that the Premini has a separate CSK. The Premini phone is graded a lot higher in control and comfort. The user opinions show that the separated CSK is a contributing factor to the feeling of control. If the rocker key does not have a separate CSK it is preferable (according to the test result and user opinions) not to have an imitation key to enhance the experienced control of the CSK. A rocker key without a CSK does not increase or decrease the number of errors. However, the user opinions imply that a rocker with a separated CSK makes the user experience more control.

11.3 Joystick

1. How does the surrounding of the joystick affect the navigation?

According to the user opinions the usability of the joystick is mainly affected by the surrounding of the joystick. Two of the phones, SE K750 and SE W800, got good results in both control and comfort. SE K700 got ranked as the worst joystick and this result is supported by the objective data of the test (more errors and increased time).

Figure 11.1. Cross-section of three mobile phones which illustrates the space when grasping the joystick. Left: SE K700, Middle: SE K750, Right: SE W800.

The joystick of the SE K750 is located in a crater and the joystick of the SE W800 is slightly elevated which makes the joystick more available for the thumb, as seen in Figure 11.1. The SE K700s joystick is not elevated enough and its surrounding is very flat which makes it difficult to get a hold of the side of the joystick.

2. How does the shape of the joystick affect the navigation?

Three of the joystick phones had different top areas, shaped like a square (SE T630) or shaped round (SE K750 and SE W800). They all got about the same ranking of control but there was a difference in comfort. The SE K750 and the SE W800 were rated as more comfortable than the T630. The SE W800 has a convex top with an abrasive material and the SE K750 has a concave top. Some of the users experienced that it was more comfortable with a concave top area while others experienced the opposite. The T630 was experienced as too sharp resulting in worse ranking in comfort.

According to the test round the shape of the joystick does not affect the feeling of control but its comfort.

12. Guidelines for Sony Ericsson

Guidelines for product planners and creative designers at Sony Ericsson

General 1(3)

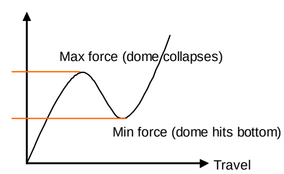
- What human factors affect the performance?
  - Experienced users make less errors and navigates faster
  - Young users make less errors and navigates faster
  - The most significant factor is the size of the thumb. (Larger thumbs make more errors > every millimeter is important)

General 2(3)

- Std SEMC dome needs 1.6 N to collapse > experienced force depend greatly on shape & surface area
  - Smaller key experienced hard to press
  - Larger key experienced soft to press
- Sharp edges on joysticks or rocker keys increases experienced force
- Navigation devices with a click ratio below 0.17 was experienced indistinct

Nokia 6630

Moa



Click ratio = (max force-min force) / max force

General 3(3)

- When to choose joystick or rocker key?
  - If there is enough space, a rocker key is preferred > W550 (Ellen) best navigation device both objective and subjective
    - Joystick is more usability efficient when small dimensions are required
    - No significant difference in performance & experience between joystick and rocker key
    - Joystick is experienced to have control navigating heads up
  - SEMC strategy > rocker key on entry phones > based on 1st impression
  - Based on usability test > joystick might be an option when small dimensions are required, even on entry phones

Design of Rocker key 1(3)

- Tactile separation between CSK and direction key > to prevent accidental activation
  - Embossing edges of direction key > increasing efficient distance to CSK
  - Adding topography onto direction key > users feel more secure where to press
  - Different material between CSK and direction key > users feel more secure where to press

Ellen

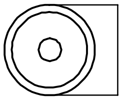
Premini

Violetta

Vicky

Design of Rocker key 2(3)

- With separate centre selection key
  - Users experience more control
  - Minimum diameter is 13 mm (updated from design of Premini-II)
  - Recommended diameter is 18 mm



min 13 mm
rec 18 mm

- Without separate centre selection key
  - Does not affect performance
  - Users experience lack of control

Nokia 6630

Design of Rocker keys 3(3)

- Key shape is more important than size
  - Large rocker keys are more “forgiving” to design
  - Design of small rocker keys is crucial > Premini / Moa > same size but significant difference in experienced control

Violetta

Ellen

Premini

Moa

Design of Joystick 1(2)

- Surrounding is most crucial factor > improves experienced control
  - Important for the thumb to be able to access the side of the joystick

Cora

Clara

Carola

Design of Joystick 2(2)

- Shape of joystick
  - Round joystick is experienced more comfortable than rectangular due to sharp corners
  - Convex top with abrasive material or concave top with sharp edges prevent thumb from slipping


Nora


Carola


Clara

Good

SE W550 (Ellen)

+ embossed edges
+ topography
+ different material
+ high click ratio

SE W800 (Carola)

+ surrounding allows access
+ comfortable shape

Bad

SE J220 (Moa)

- high force and sharp edges
- bad tactile separation
- low click ratio

SE K700 (Cora)

- Inefficient separation makes it hard to access

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Appendix

Appendix A: Questionnaire

BAKGRUNDSFORMULÄR

PERSONLIG INFORMATION				
Namn:				☐ M ☐ K
Ålder:				
Yrke:				
Arbetsplats:				
Tumbredd:				
TEKNISK INFORMATION				
Vilken mobiltelefon använder du idag?				
Vilka mobiltelefoner har du haft tidigare?				
Hur länge har du använt din nuvarande telefon?	☐ > 2 år	☐ 1-2 år	☐ ½-1 år	☐ < ½ år
Hur ofta ringer du med din mobiltelefon?	☐ > 5 ggr/dag	☐ 3-5 ggr/dag	☐ 1-2 ggr/dag	☐ < 1 gång/dag
Hur ofta skriver du SMS?	☐ > 5 ggr/dag	☐ 3-5 ggr/dag	☐ 1-2 ggr/dag	☐ < 1 gång/dag
Vilka funktioner använder du i din mobiltelefon?	☐ Telefonbok ☐ Kalender ☐ MMS ☐ Kamera ☐ Spel ☐ Internet ☐ Bluetooth ☐ Musik ☐ Alarm ☐ Övrigt ________________________			
Hur skulle du beskriva dina tekniska färdigheter?	☐ Mycket bra	☐ Bra	☐ Ok	☐ Dåliga

Appendix B: Measurements

Dimension	Sony Ericsson				
Joystick phones	T630	K750	K700	W800	J300i
Mobile phone					
Width	43,5	46	47	46,5	43
Length	101,5	99,5	99	100	99
Thickness	19	21	22	21	22
Navigation	19,5	19	12,5	15	12,5
Navigation->Keypad	1,5	0	1,5	1,5	2
Keypad->Bottom	8,5	7	8,5	7	10
Keypad					
Width	35	35	35	35	29
Length	23	23	20,5	22	22
Centre to Centre (Horizontal)	12	12	13	11,5	9
Centre to Centre (Vertical)	5,5	5,5	5	5,5	6
Width of keys	10	11	10	11	9
Height of keys	6	5,5	5	4,5	4
Distance between keys (Horizontal)	0	0	2	0	0
Distance between keys (Vertical)	0	0	0	1	2
Joystick					
Diameter	13	13,5	12,5	12	12,5
Top area (diameter)	3,5	4	5	4	4,5
Weight					
Mobile phone	92	102		101	77
Activation force and travel					
Keys - Force	2,57	3,06	2.81	2,96	2,51
Keys - Travel	0.04	0.03	0.03	0.05	0.03
Joystick/CSK - Force	1,46	1,5	1.41	1,53	1,42
Joystick/CSK - Travel	0.08	0.09	0.09	0.08	0.09

Dimension	Premini	Nokia		Sony Ericsson				
Rocker key phones	II	6630	N70	Z800i	W550i	Z1010	W810	J220
Mobile phone								
Width	45		52	48,5	47			44
Length	104		109	177	142			103
Thickness	19		21	12	16			19
Navigation	13		12,5	23	20			12,5
Navigation->Keypad	3		0	2	13			1
Keypad->Bottom	8		6	17	25			10
Keypad								
Width	33		29	41	36			32
Length	18		19,5	39	24			23
Centre to Centre (Horizontal)	11		9,5	13	13			11
Centre to Centre (Vertical)	4,5		4,5	8	6			5,5
Width of keys	11		9,5	13	10			9
Height of keys	2		5	6	6			4,5
Distance between keys (Horizontal)	0		0	0	3			3
Distance between keys (Vertical)	3		0	1,5	0			1
Rocker Key								
Diameter	13		13	19	17			12,5
Centre to Centre (Horizontal)	6		5,5	7	7			6
Centre to Centre (Vertical)	6		5,5	7	7			5,5
Diameter CSK	5		4	7	8			3
Weight							-	
Mobile phone	94			118	121			85
Activation force and travel							-	
Keys - Force	1,3	2	1,91	2,18	2,33	2.13	2.55	2,97
Keys - Travel	0.05	0.03	0.02	0.05	0.04	0.06	0.04	0.02
Joystick/CSK - Force	1,21	4.73	3,77	2	1,91	2.15	2.44	2,48
Joystick/CSK - Travel	0.06	0.02	0.02	0.06	0.05	0.05	0.02	0.02
Rocker down - Force	1,25	1.98	2,07	2,2	2,28	2.9	2.38	3,37
Rocker down - Travel	0.05	0.02	0.02	0.05	0.05	0.04	0.02	0.02