Navigating Navigation
A Safety and Usability Evaluation of the Volvo P1 Navigation System

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Anders Lindgren

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Abstract

Navigation systems are today options provided by car manufacturers’ world wide and market predictions suggest that 25 percent of all cars produced by 2009 will have navigation systems installed. However, there are many human-interface issues concerning the use of these navigation systems. This thesis describes a study which evaluates and tests the safety and usability of the Volvo P1 navigation system and also contains suggestions on how the system and its controls should be designed to be safer and easier to use. This is done through heuristic evaluations and a Lane Change Test (LCT). The LCT is used to compare the level of driver distraction between the steering wheel control and remote control and also between common and advanced exercises in the system. Results from the study shows that there are no significant differences in distraction between using the steering wheel control or the remote control. The results also show that there are no significant differences in distraction between the common and advanced exercises. The results of the study are presented as a collection of design proposals that can be used to improve the system’s safety and usability.

Keywords:
Navigation Systems, Usability, Safety, Driver Distraction, Lane Change Test.
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“GOOD DESIGN IS NOT ONLY A MATTER OF STYLING THE SURFACE. IT IS JUST AS IMPORTANT TO MAKE THE PRODUCT EASY TO UNDERSTAND AND USE. IF THE PRODUCT IS NOT FUNCTIONAL, IT CAN’T BE BEAUTIFUL”.

(The Volvo design philosophy)
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1 Introduction

The task of driving consists of a set of activities requiring perception, cognition, motor response, planning and task selection (Green, 1993). In recent years, the range of information equipment available to the driver has grown considerably. In-vehicle driver information is one of the recent applications and as the products are emerging, there is an increasing need of knowledge about drivers and their interaction with the system.

In designing navigation systems the general issue is about what information that should be shown on the display and in what form. Visual information requires the driver to inspect the display from time to time and is thereby producing some amount of visual workload, which may bring forth unsafe driving behaviour. This problem brings forth the discussion of how to interact with the system and what kind of medium that should be used to cause as little distraction as possible.

Volvo was found in 1924 and the first car, the 1944cc Jakob, was in production by 1927. Ever since the first car left the factory, focus has always been on safety and today more than 13 million cars have rolled out of the Volvo factories. Today Volvo Cars Corporation (VCC) is owned by Ford Motor Company along with brands like Jaguar and Aston Martin and in 2004 the sales increased to a record high 456,000 sold cars.

1.1 Purpose

The purpose of this thesis is to evaluate and improve the usability and safety when using Volvo’s in-vehicle navigation systems. This is achieved through quantitative safety and usability testing as well as usability evaluations based on expert interviews and heuristics. The two main safety focuses are on investigating which of the two navigation system controls (steering wheel and remote control) that is the most distracting to the driver and to find out if more advanced functions in the system are more distracting to carry out while driving than more common ones.
The main objects of the thesis work are to get an understanding of how the users experience Volvo’s navigation system and what parts of the system that they find easy or difficult to use. This purpose brings forth the following problem statements:

- Which one of the steering wheel control and remote control is the most distracting to use while driving?
- Are the advanced navigation system exercises more distracting to carry out than the common ones?
- How should the system be designed to be more usable and less distracting to use as a secondary task?

### 1.2 Delimitations

Some limitations were set for this thesis. Firstly, no prototypes were being built, only suggestions on how to increase usability and safety from the different tests and evaluations were conducted. Secondly, no implementations were made, neither in prototypes nor the existing system. Finally, the navigation system controls were not tested in real traffic but only in a simulator environment.

### 1.3 Targeted Readers

This thesis is primarily written for students with similar educational background, generally interested in safety/usability testing and evaluation. Secondarily it can of interest for Volvo Cars Corporation as a help in improving their navigation systems and thirdly for people with a genuine interest in interaction design and human behaviour in complex systems.

### 1.4 Report Overview

The *Theoretical Framework* chapter defines the terms usability, interaction design and different design principles as well as describes safety issues such as different kinds of human workload. Moreover, theories around navigation systems and the ways of interacting with them are presented and the chapter ends with a short briefing on earlier work and descriptions on methods about how to test and evaluate navigation systems.

The *Method* chapter presents a review of how the different tests and evaluations were carried out. Data gathered from the testing and evaluation is presented in the chapter *Results* and the thesis is rounded off with a general *Discussion* followed by the chapters *Future Research* and *Conclusion.*
2 Background

This background chapter reviews the history, present, and future of Volvo Car Corporation. It ends with a short introduction and description of the navigation system investigated in this study and the car models in which the system is available.

“CARS ARE DRIVEN BY PEOPLE. THE GUIDING PRINCIPLE BEHIND EVERYTHING WE MAKE AT VOLVO, THEREFORE, IS – AND MUST REMAIN – SAFETY.”

Assar Gabrielsson and Gustaf Larson
The founders of Volvo

2.1 Brief History of Volvo

Volvo was found in Gothenburg, Sweden, by Assar Gabrielsson and Gustaf Larsson. The intention was to build a vehicle better suited for the Scandinavian climate than were US imports. The first series-built car, the 1944cc Jakob, left the factory in 1927. Gabrielsson and Larsson were quick to declare that Volvo’s activities should be based on human concerns and as a result, the core value of the company’s operations, products and actions is safety (Volvo Pocket Guide, 2005).
2.2 Volvo Today
Since 1999 the Volvo Car Corporation (VCC) has been owned by Ford Motor Company. Along with Aston Martin, Jaguar and Land Rover, VCC is part of Ford’s Premier Automotive Group where it functions as a “Center of Excellence for Safety”. This means that safety research carried out by VCC has a strong influence on all car brands within the Ford group.

Volvo’s head office is located in Gothenburg, Sweden and the number of employees at the company was 27,575 in December 2004. The company’s global network of dealers and service workshops employs an additional 22,500 people.

In 2004, Volvo’s sales were 456,000 vehicles and as a total, Volvo has produced 13,296,506 cars since the first vehicle rolled out the factory in 1927.

2.3 The P1 Navigation System
Volvo’s navigation systems are options designed to further increase the driving experience. They are to assist the driver in finding the fastest route to the desired destination or help in finding the nearest hotel, petrol station, restaurants and so on. On the display screen, the driver can see his/her geographic location and the distance left to the desired destination. Audible
instructions guide the driver when necessary by e.g. telling when to turn in crossing etc. The driver is also receiving in advance warnings of traffic tailbacks and suggestions for alternative routes. The Volvo P1 navigation system that is being evaluated in this thesis is currently sold as an extra option in the models V50 (Figure 1) and S40 (Figure 2).

![Figure 5: Interior Design S40/V50](image)

**Steering Wheel Control**
The steering wheel control (Figure 4) is located on the back side of the steering wheel (Figure 5) and is controlled with the fingertips. It consists of a small joystick to navigate in the menus as well as a “Back” button and an “Enter Button”. Information on how this control works is presented later in the thesis.

**Remote Control**
There is also another way of interacting with the system and that is by using a remote control (Figure 6). The control is originally designed to be used by a passenger or by the driver while the...
car is not moving. However, studies have shown that many users tend to use the remote control also while driving and this is going against the safety thinking at Volvo, with the focus on the driver keeping his/her hands on the steering wheel.
3. Theoretical Background

This chapter includes theory about usability, knowing the user, and different design principles as well as describes some possible car safety issues such as different kinds of human workload. It ends with a short briefing on earlier work and some descriptions on how to test and evaluate navigation systems.

3.1 Usability Engineering

Not many years ago, it was generally considered that users had to learn and adapt to a system or application. Today there is a different approach and most developers agree that instead, technology should be adapted to the users. To achieve this, companies have brought psychological aspects into the development process of human-computer-interaction systems (Johansson, 2001).

When designing a human computer system, one of the biggest problems is to make sure that the finished product is what the user really wants and need. If you know what the user wants and need, you can produce the best system for that particular task and that particular user working in a particular environment. This is what in ergonomics is known as Know the user! Know the task! By know the user is meant, that there should be an understanding of who the users are, what expertise they have, and what they are likely to think about systems and the environment there are operating in (Faulkner, 2000).

The main rule of usability engineering is to test early and often. The early testing during the development of a user interface is the key to identifying potential usability problems at a time when there is still time for changes (Redish et al. 2002).

3.1.1 The Need for Usability and Good Human Factors

Today the quality of interfaces has improved very much, but user requirements are higher and applications more demanding than ever before. Innovations are
important, but much work must be done to help novice and experienced users’ fight the many remaining frustrations. Therefore, human performance and user experience with information systems will continue to be a quickly expanding research and development topic in the future decades (Shneiderman, 2005).

### 3.1.2 What Happens Without Usability Engineering?

If usability is not prioritised, the dangers are that the system may not look or behave like the user wants it to do. The idea of usability engineering is helping the design process open and measuring results with criteria that have been agreed upon in advance. Usability engineers can help to guarantee the visibility of decisions because they are aware of the user’s needs and the problem that may occur during the development of a system (Faulkner, 2000).

### 3.2 Knowing the User

Knowing the user is a difficult and often undervalued goal. No one would argue against the principle but many designers think that they understand the user and the user’s tasks. All design should begin with an understanding of the intended users, understanding that users from different cultures etc. have different requirements and attitudes towards technology (Shneiderman, 2005).

Getting to know the users is a never-ending process because there is so much to know and because the users keep changing. Shneiderman (2005) separates users into novice or first-time, knowledgeable intermittent and expert frequent users:

**Novice or First-time Users**

The novice users are assumed to know little of the task or the interface concepts. By contrast, first-time users (for example a business traveller using a rental car’s navigation system) are professionals who know the task concepts but have little knowledge in the interface concepts. For these users, the number of actions should be small, so that they can carry out the most basic tasks and gain positive reinforcement. Further, informative feedback is helpful and carefully designed user manuals and/or visual tutorials may be effective.

**Knowledgeable Intermittent Users**

Many users are knowledgeable but intermittent users of a variety of systems. They have stable task concepts and knowledge of interface concepts, but may have difficulties in retaining the menu structure or the location of features. To help these
users, orderly structure in the menus, consistent terminology and consistent sequences of action, are recommended.

**Expert Frequent Users**
These users are truly familiar with the task and intercept concepts and are looking to get their work done quickly. The demands for this type of users are rapid response times, brief and non-distracting feedback and shortcuts to carry out actions performed regularly.

Shneiderman continues with pointing out that designing for one of these groups of users is easy but that designing for several of them is much more difficult. When one system must accommodate multiple user classes, the basic strategy is to permit a *multi-layer* (also called *level-structured*) approach to learning, meaning that novices can learn a minimal subset of objects and actions with which to get started. The idea with this is that the novice users then are likely to make correct choices when the numbers of alternative actions to make are limited. After gaining experience, the users can select to enter more complex levels of the system.

Another component of accommodating different usage classes is to allow user control of the amount of feedback that the system should be providing. Novices want more informative feedback to confirm their actions, while frequent users want less distracting feedback and get a faster pace in the interaction.

### 3.2.2 User Frustration

There are several things in a badly designed system that can cause frustration among its users:

- When the system does not do or does not act like the user wants it to.
- When the system does not supply the user with sufficient information of what to do.
- When the appearance of an interface is too noisy, complex or dazzling.
- When the system requires the user to carry out too many steps in performing a task

To avoid or at least reduce the frustration, Preece et al. (2002) suggest, that interfaces should be designed to be simple, perceptually salient and elegant. Besides that, it should be designed with concern to usability design principles, well-thought-out graphic design principles and ergonomic guidelines.
3.3 Workload

When considering the design of a navigation system, it is important to keep in mind cognitive aspects such as workload. Workload is the demand that is placed upon humans when e.g. interacting with a navigation system. A change in workload can make people change their behavior, which may or may not affect their performance (Rouse et al. 1993). The level of workload is a product of the interaction between the operator and the characteristics of the work task (Macdonald, 1999).

Results from earlier studies confirm that different types of secondary tasks have different workload on a user and that the amount of workload can vary considerably due to the difficulty of the task (Iqbal et al. 2005). Research has also shown that the level of similarity between different tasks also play a big role when it comes to peoples performance. Similar activities have shown to be more difficult to carry out simultaneously than activities that are relatively dissimilar (Lundh et al. 1992). The reason for this is that; the greater the similarity between the components of two tasks, the more likely they are to demand the same processing resources at the same time, and thereby produce mutual interference (Reason, 1990).

3.3.1 Data Overload

If our human capacity to process information was unlimited, the level of workload associated with a task would not be a problem. However, since our human capacity is limited, the result of exceeding the limit is that people make mistakes and occasionally have accidents. When drivers becomes overloaded, they begin to neglect to search some of the information sources (e.g. the rear-view mirror) or begin to miss information (e.g. fail to see that the car in front is slowing down) because they search the information source too infrequently. It is not only the capacity to handle incoming information that is limited; also the handling in terms of output is restricted. People are limited in the ability to manipulate the information received and in the rate at with they can make decisions (Smiley, 1989).

Technical advances are continuously made to help people better understand and manage a host of activities. The computerisation of the modern world has advanced our ability to collect, transmit and transform data. However, as discussed earlier, people’s ability to interpret this increasing amount of data has been expanding much more slowly, if at all (Woods et al. 2002).

There are three basic data overload problems (Woods et al. 2002):
1. There is *too much data* on the screen and that causes a clutter problem. This type of data overload can be solved by simply reducing the number of data units that are displayed. Instead of removing data though, some propose to push some data into the background and provide navigational techniques so that the users can reach that data when necessary.

2. Data overload creates a *workload bottleneck* where there is too much to do in the time available. That problem can be solved by using automation and other technologies to perform activities for the user or to help and cooperate with the user during these activities by for example highlighting the alternatives.

3. Overload can occur from users having problems in finding the significance of data when they do not recognize in advance what data from a large data field that will be informative. As a solution to this Woods recommends that we should represent the data field in such a way that the significant data naturally emerges from the perceptual field.

### 3.3.2 Reducing Workload

Due to the high visual workload that driving tasks creates the major development of user interfaces concerns reduction of this visual load. This can be achieved by using other transmission channels than visual, like language etc. If visual attention is needed for obtaining information, the relevant outputs should be presented near the line of sight to lessen eyes-off-time and thereby reducing visual workload (Roessger, 2000). By putting more effort in designing a usable system as a well defined secondary task, the system also becomes safer, requiring less attention and being less time consuming (Alpern & Minardo, 2003; Somervell et al. 2002).

Efforts to improve the user interface are also cognitively important when it comes to tighten the loop between the user and the system, making it easier for the user to obtain important information from the system through the display. By shortening the amount of time it takes to select pieces of information the cognitive load decreases. Even a few seconds of delay, due to the difficulty of the interface, can radically reduce the rate of information received by the user. When this happens and the user is forced to move the attention from the primary task to the system interface itself, the effect can be distressing to the thought process (Ware, 2004).
3.3.3 Why Measure Workload?
Although it is preferable to predict workload and performance before a system is designed it is often essential to measure the amount of workload in an already existing system. This should be made to identify overload problems in the system (e.g. the workload bottlenecks discussed in 3.3.1) where resource demands exceed the desired limits and performance breaks down. Alternatively, workload may be measured to compare two alternate pieces of equipment that may execute similar functions in the system but differ in their resource demands. Sometimes the workload criterion is the only satisfying criterion when it comes to selecting between different alternatives (Wickens & Hollands, 2000).

It is also important for designers to realize that performance is not all that matters in the design of a good system. It is of equal importance to consider what demands a task imposes on the user’s limited resources. Research made by Wickens and Hollands (2000) has shown that cognitive demands may or may not correspond with performance. When assessing or comparing the workload of systems, the purpose of such a comparison is to optimize the system.

3.4 Navigation Systems
Current in-vehicle navigation systems are capable of providing reasonably accurate, trustworthy door-to-door guidance and market predictions suggest that 25 percent of all cars produced by 2009 will have navigation systems installed. (Nowakowski et al. 2003). However, there are several things to contemplate when designing a usable navigation system.

3.4.1 Safety Concerns
An action like inputting a destination is a cognitively complex act that tends to absorb the driver’s attention to a degree that may cause dangerous traffic situations. The interfaces of navigation systems today are highly questionable from a safety point even in low-traffic conditions. Still it cannot be assumed that drivers will pay attention to the system’s advice not to input navigation instructions while the vehicle is moving (Bernsen & Dybkær, 2001).

There are many human-interface issues concerning the use of in-vehicle navigation systems. The most fundamental concern is the risk of increased workload and possible overload discussed earlier in this chapter. The main task in a vehicle is still driving, meaning that only limited visual and mental capacities are obtainable for
secondary tasks, like using the navigation system (Roessger, 2000; Barrow, 1991; Chiang, 2004). Whether or not this leads to an overload depends on the number of tasks competing for attention, the nature of these tasks, and the status of the surrounding environment. The driver may be able to handle a number of items competing for attention if the driving task is relatively uncomplicated and if the other tasks are relatively undemanding. On the other hand, a single task in addition to the main task of driving can cause an unacceptable workload if the driving task is essentially difficult, for example driving on a curvy road (Green, 1993).

### 3.4.2 Designing for Safety

As mentioned before, the usage of navigation systems while driving is a cognitively complex act. Car navigation systems are safety critical system often used by novices such as drivers of rental cars. Therefore, the system has to be easy to learn and simple to use while driving and the information displayed on the screen should be understood at a glance. Problems like poor feedback and unintuitive usage of buttons or knobs are equally critical if they are to cause mistakes or confusion during driving (Curzon, 2002). To improve usability more, it is important to consider not only the physiological and shape-related characteristics of the human interface from the ergonomic engineering standpoint, but also from the cognitive aspects of how humans think and behave (Kunimitsu et al. 1999).

In designing navigation systems, one general issue is about what information that should be shown and in what form (Williams & Green, 1993; Barfield & Dingus, 1998). Information presented at a set moment allows the driver to determine when to read the information. This may reduce mental workload, since the driver has the chance to adjust the interaction with the system in a way that it will not affect the driving performance too much. Even though that is good, the visual information still requires the driver to actually inspect the display at some time, and thereby producing some amount of visual workload, that may bring forth unsafe driving behaviour (Janssen et al. 1999; Barrow, 1991; Burnett & Joyner, 1993; Nilsson et al. 1998; Moldenhauer & McCrickard, 2003; Harbluk & Noy, 2002; Alpern & Minardo, 2003; Little, 1997).

Studies also show that for safety reasons, drivers should not be distracted from the driving task for longer than two seconds. Therefore, it is important that a task does not require the driver’s attention for more than one or two seconds per interaction. That is, the driver must be capable of interrupting the interaction with the system at
least after one to two seconds and be able to resume the interaction after the interruption without losing in performance quality (Baumann et al. 2004).

Marcus (2004) points out that, in designing for safety, it is important that:

- Displays must be readable at a one-second glance.
- Everything must be designed to avoid driver distraction, for example, most tasks must be divided into small steps.
- The design is simple to increase clarity and the driver’s confidence.

Another way of reducing the interference between driving and secondary tasks is by limiting the functions available to the driver while driving. The functionality of in-vehicle systems should be limited to tasks that do not significantly interfere with the driving task, that have benefits that outweigh the cost of including the function and functions that will be used frequently (Marcus, 2004).

### 3.4.3 Cognitive Characteristics Influencing Driver Behaviour

Multiple factors such as the system’s functional capabilities, environmental factors and driver characteristics provides the context for driver interaction with the navigation system and plays an important role in determining what kind of information that should be presented to the driver. Driver behaviour and the related design implications depend on understanding both the driver’s cognitive characteristics and the context in which the driver operates. For example, the characteristics of private and commercial drivers do not have to differ radically, but their information requirements and interaction with the navigation system will certainly differ.

According to Barfield and Dingus (1998), there are three areas of cognitive characteristics that influence driver behaviour. The first area addresses perceptual and motor limitations that affect the driver’s information access and response capabilities. As an example, visual attention and limited glance time requires design considerations such as limiting the information available to the driver.

The second area explains the characteristics that might influence how well the driver understands and integrate the information received, e.g. how the driver selects from multiple options. This limited focused attention needs design considerations such as recognizing the potential to distract drivers from their main task with excessive information.
The third area describes characteristics that define how the driver develop and organize knowledge and the factors that influence driver attitudes. As an example, different levels of navigation expertise require the system to provide drivers with navigation information customized to fit their level of expertise.

Although obviously navigation systems are demanding, they can reduce workload as well. According to Moldenhauer & McCrickard (2003), Llaneras & Singer (2002) and Gstalter & Fastenmeier (1990), navigation systems can improve the driving experience by helping the driver to navigate in unfamiliar settings and thereby reduce the mental workload of remembering where to go. Other research made by Stevens et al. (2000) discusses the importance of recognizing that although the navigation system may encourage the driver to briefly look away from the road, it may still be preferable to using for example, a conventional paper map.

3.4.4 Different Kinds of Input
There are several different ways of interacting with a navigation system. Different manufacturers have different opinions on what type of interaction that is the most efficient and usable.

**Voice-based Interaction**
As noted earlier, many navigation systems require visual attention while inputting information or reading the visual output. Some manufacturers have tried to overcome this problem by introducing speech recognition technology. The main advantage of this technology is that it allows the driver to keep his/her eyes on the road and hands on the steering wheel while interacting with the system (Harbluk & Noy, 2002; Burnett, 2000). However, these voice-based interactions are not effortless and researchers have started to worry that these kinds of systems also have the potential to distract drivers and create unsafe situations (Harbluk & Noy, 2002).

Also, although the interaction mode has changed, allowing the driver to maintain visual contact with the environment, these interactions may still have a significant cognitive component, resulting in increased driver workload. The increase in cognitive demand, experienced from drivers using voice-based systems can arise from two sources. First, the driver has to maintain a cognitive model of the system in use. This can be difficult for voice-based technologies where there is no manual feedback, and if any, very little auditory feedback. The second and perhaps more important source is the workload component due to the requirements of the
transaction that is being carried out by using the system. If the driver has a complex interaction with the system, it is likely to increase workload more than the easier tasks manoeuvred on a daily basis would do (Harbluk & Noy, 2002).

Another issue is that drivers do not necessarily manage their voice-based interaction effectively as they are to take risks during the interactions and failing to compensate for the slower reaction times. These voice based interactions with in-vehicle navigation systems also share many of the characteristics of mobile phone conversation and may have the same effect on driving performance (Jonsson et al. 2004). Perhaps some of these reasons are why voice-based interaction, that was the general solution a few years ago, was replaced in 2004 by a variety of mechanical approaches (Diem, 2004).

**Touch Screen**

Much of the current discussions around navigation systems involve touch screens. Stevens et al. (2002); Barfield & Dingus (1998); Burnett & Porter and Kaasinen (2002) all point out that these kinds of systems provide no tactile feedback concerning control orientation, location or function and can thereby not be operated with focus on the road. Touch screens also tend to require high visual demand from the driver when needing to locate virtual controls on the display (Llaneras & Singer, 2002).

Studies have shown evidence of an unacceptable increase in lane deviation with the use of touch screen controls and research also shows that the use of touch screen controls while driving demands greater visual glance time and results in larger driving and system task errors than for example conventional hard buttons. The reason for this is mainly the lack of feedback but also that the touch screen’s controls looks (e.g. size, colour) changes depending on the screen. Therefore, touch screens can be a very good method for pre-drive or zero-speed cases but should not be used while driving (Barfield & Dingus, 1998).

One advantage that touch screen displays have though is that they require substantially fewer interactions than non-touch screen interfaces to accomplish destination entry tasks. In a study by Llaneras & Singer (2002) the average numbers of keystrokes were 6.85 for touch screens input and 11 for non-touch screens. Another advantage of the touch screen is that it eliminates the need of both highlighting and selecting menu items and thereby reducing a two-step procedure into a single operation.
Knobs & Hardbuttons
There is a trade-off between hard buttons and touch screens that has become a concern of the human factors community. As described earlier, touch screen controls demands greater visual glance time, a disadvantage compared to knobs and hardbuttons that can be glanced at briefly to find the control and then be controlled using haptic (tactile and kinaesthetic) information (Barfield & Dingus, 1998). Also Roessger (2000) suggests that switches and knobs should be used to provide the user with haptic feedback and thereby minimize the visual load.

Several studies show that destination entry while driving is too distracting to be carried out in a safe way. They point out that visual-manual methods of destination entry, such as using knobs or hardbuttons, leads to lengthier completion time, longer eyes-off-road time and more frequent glances to the device (Tijerina et al. 1998; ElBoghdady, 2000). It also increases the number of lane exceedences compared with for example a voice input system. However, according to Tijerina (1998), voice based systems are associated with longer and more frequent glances away from the road scene to contain information about the destination.

One advantage of using knobs or hardbuttons is that there is an increased interest within the human-machine interaction (HMI) field for the use of haptic information. Humans are capable of sensing a large variety of haptic features, such as shapes and textures. This makes it possible for traditional manual controls to provide information considering their function, current status and mode of operation, information that can be acquired without adding too much visual load (Burnett & Porter, 2001). A certain amount of visual load is however impossible to escape from, to input a destination, the driver has to scan the available options on the display and make a choice with the knob or button. When confirming the choice, new information is being displayed and the user must again scan the screen (Bernsen & Dybkær, 2001).

3.4.5 Different Proposals for System Design

Menu Design
Menus make it easier for the user to make a choice from a limited set of options. The ideal menu displays the current position, along with the name of the parent and grandparent menu in the hierarchical structure.

When designing a menu, there is a trade-off between the width and depth of the menu. Having too many options in each level will give a shallow menu, but
keeping the menus short may result in very deep menus that can be equally challenging to navigate. In cognitive psychology, the magic number of seven is often mentioned as the number of chunks of information that can be retained in short-term memory (Sternberg, 1999). If considering that, menus greater than seven choices in length will be harder to use than those smaller than seven.

Even despite what the psychology texts suggests, experiments have shown that menus with few levels and many alternatives work better than menus with many levels and only few alternatives (Murphy, 2002; Shneiderman, 2005). In situations with small screens and restricted space it may not be possible to make the entire menu visible at once. A useful tool in that kind of situation is a scrollbar that enables the user to find more alternatives in a shallower menu structure (Murphy, 2002). For the frequent users, shortcuts in the systems menus should be provided, allowing the user to increase the pace of the interaction with the system.

Barfield & Dingus (1998) presents a number of guidelines for designing menus:

- Each page of menu options should have a title that clearly shows the purpose of that menu.
- Menu titles and options must be precisely named and have the same contextual references that the user will have.
- The navigation system should present menu selections only for currently available actions.
- Menus should be presented in a consistent format throughout the system.
- Menu selection should be listed in a logical order or, if that is impossible, in the order of frequency of use.
- If using hierarchical menus, the user should be able to return to the former higher menu-level by using a single key action until the top-level is reached.
- The feedback in the menu system should indicate:
  - What options that are selectable
  - When an option can be selected
  - What options that have been selected so far
  - The end of the selection process

Control Design
According to Stevens et al. (2002), controls should be easy to reach and manage from a normal driving position and not interfere with normal hand and arm movements. The controls should move in a direction that is consistent with the display and also be designed in a way that they are easily perceptible.
There are a number of different ways to aid recognition, including colour, shape, size, location and texture. Øritsland & Buur (2003) are concerned with interaction designers getting too enthusiastic with new technologies and thereby fail to preserve or transfer the qualities of use. As an example they mention the digital adjustment of settings by using buttons. Even though buttons might be more precise, they loose the feeling of being in-control and the feeling of range and proportion that analogue knobs offer.

When designing new controls it is not always clear if the purpose is to imitate the controls used in previous models of a device. A familiar appearance will give a good first expression, but it can be dangerous to sacrifice the overall quality of the interface for the looks only. The important thing, if the previous devices were successful, is that the concepts being presented to the user are the same as in the previous device. If so, the users will quickly adapt to a different appearance (Murphy, 2002).

Another important aspect in designing navigation systems is the location of the controls. The further away the controls are from the driver, the greater resources are needed to activate the control. Therefore, controls located around the steering wheel, or otherwise in close proximity of the driver are easier to use (Barfield & Dingus, 1998).

**Blind Controls**

Sometimes “blind” operation is necessary. By “blind” control is meant that the controls are not fully visible for the user when using the system. If the controls are in a blind position, they should be shape-coded so that the user easily can identify the controls by feel (Barfield & Dingus, 1998). If possible, they should also have distinguishable tactile/force feedback characteristics (Burnett & Porter, 2001).

**Movement Compatibility**

When the driver moves a control, (i.e. a position switch or rotary knob) it often changes the state of a displayed variable in the display. Wickens & Hollands (2000) refers to this as *movement compatibility*, which defines a set of expectancies that the user of a system has about how the display will respond to the action made with the control. When movement compatibility is violated, the user may move the control and perceive the system responding in what he/she thinks is the opposite direction. This may trigger a further unnecessary and potentially dangerous control action.
Feedback
The operational feedback should be appropriate, adequate and timely. The feedback is adequate if the driver clearly understands that a change has occurred in the system and that the change is a consequence of the input. A timely response should be given within 250 ms and allow the driver to directly see what mode the system is currently in and what actions that are possible to make in the current mode (Danielsson, 2001).

Consistency
The information that the system presents to the driver should be consistent, i.e. controls should remain consistent in different modes, especially if designing multi-function buttons. It is therefore important to use the same format and manner for information in different parts of the system and to use the same entry methods for similar tasks in different parts of the interface (Green, 1996). Inconsistent system will be harder for the driver to learn, cause more errors and by that irritating the driver (Stevens et al. 2002).

Sounds
By using sounds, a product can give useful feedback about the state that the system is in. A special category is navigation sounds that are continuously changing whilst the product is in use to indicate how the user of the system is progressing with some particular task (Jordan, 2000). This kind of perceptual feedback allows the user to take his eyes of the display and concentrate on the main task of driving (Green & Jordan, 1999).

Colour
Colour stands out from a neutral background and therefore, colour-coded targets are quickly and easily noticed. Therefore, colour-coding is suitable to use in a display for an effective and fast localisation. A sparing use of colour coding (a maximum of five or six colours) is recommended since too many colours create more information and an increase in search time (Wickens & Hollands, 2000; Zhaosheng et al. 2003). It is also important to use the same colour-coding rules throughout the system as differences in the usage of colour-coding may make the user hesitate and question the meaning of the colour changes (Shneiderman, 2005).

Moreover, if colours are to be perceived under conditions of glare or changing light, like e.g. on screens located on the dashboard, absolute judgement failures will be even more common. This is because colour perception is affected by ambient light and people may for example confuse red for brown (Wickens & Hollands, 2000).
Another aspect to have in mind is that the colours should be distinguishable by colour-blind people. People who are colour-blind often have problems differ colours in a red-green direction but almost everyone can distinguish colours that vary in a yellow-blue direction. (Ware, 2004)

People see different colours in different ways and scientists use the technical term saturation referring to how pure colours seen to the viewer. A high-saturation colour is bright and a low-saturation colour is close to black, white or grey. When designing a display research has shown that highly saturated red, green and blue colours are the easiest to find for the user (Ware, 2004).

Another technique is highlighting with the help of colours and studies of this have shown that this method results in quicker and more accurate recognition of targets in a visual display (Barfield & Dingus, 1998).

**Tutorials**
When trying to learn an electric media, tutorials can be of great help. One way of demonstrating how to use a system is by using animated demonstrations that have been shown being more effective at describing the use of a system than static explanations such as an instruction book. Moreover, studies have shown users to be faster and more accurate in performing tasks after being showed an animated demonstration than when been reading a textual explanation. However, research has also shown that the positive effect on time and error was reversed after some time, showing the limitations of using animations as a teaching tool. Researchers therefore suggest that tutorials should be reinforced with textual explanations like instruction books (Shneiderman, 2005).

**3.5 Manufacturers' Responsibility**
Even if the choice of using a car navigation system is not obligatory, the system manufacturers have a responsibility to society in producing as safe systems as possible. These safety concerns should be dominant in decision making, but they can also lead to trade-offs in other aspects of the system (Moldenhauer & McCrickard, 2003).

In these safety critical applications, the most common trade-off is between safety and usability (Murphy, 1996). Drivers often want to understand where they are driving in addition to get there safely. The relation between safety, understanding and the other measures of user satisfactions tend to be unclear (Moldenhauer &
McCrickard, 2003). Manufacturers should therefore assume that if they do not directly instruct that a particular function is not to be used while driving, or physically disable a function when the vehicle is in motion, the driver is likely to assume that the function can be carried out while driving (Stevens et al. 2002).

**The 15-second Rule**
Evidence showing that information demands in in-vehicle navigation systems causes overload is concerning many instances. The Society of Automobile Engineers (SAE) et al. has been developing standards, trying to increase product safety and usability, both by design and assessment. This has resulted in SAEJ2364 (Recommended Practise for Navigation and Route Guidance Function Accessibility While Driving), a paper which specifies rules of what a driver not should be allowed to do with a navigation system while the vehicle is moving. SAEJ2364 states that no tasks, such as entering a destination, should take more than 15 seconds to complete, when measured as a continuous task. The 15-second limit is based upon investigations of fatalities and injuries from long task times and glance sequences, common human factors principles, human performance limitations etc. When measuring the completion time, timing starts when the driver’s hand leaves the steering wheel and ends when feedback is received for the last input action (Green, 1999).

Although the work of setting standards for safety is appreciated by many, Stevens (1999) notes that a standard cannot specify all the necessary requirements to produce safe navigation systems or identify all possible safety risks. Stevens also points out that HMI-related standards may encourage better HMI design but cannot guarantee the overall consequences concerning safety in a new system.

**Safety Principles for In-vehicle Information and Communication Systems**
As early as in 1991, Kurt Barrow wanted to place limitations in the navigation systems. For example, a standstill map usage would require the driver to stop the vehicle before a map would be displayed. The idea behind this is to force the driver to be relieved from the task of map reading and Barrow points out that this may be essential to ensure the safety rights of other drivers on the road. Another restriction suggestion was allowing only certain people to use the system, requiring operators to be licensed to use the system (Barrow, 1991).

Even though Barrow’s thoughts and ideas were presented in the “stone age” of graphical navigation systems, they are still compatible with much of today’s ideas concerning safety in the systems. The European Commission have stated principles
to driver information and communication systems used by the driver while driving (Stevens, 2000). These principles include:

*Information Presentation* – Information should be presented in a clear and simple form, which should be appropriate, accurate and timely. For example, the system should be designed so that it does not distract or visually entertain the driver.

*Interaction with Display and Controls* – The driver should be able to interact with the display and controls and still be able to attend to the main task of driving. For example, visually displayed information should be designed so that the driver can understand it with a few glances that are short enough to not affect driving in a negative way.

*System behaviour* – What should and should not be accessible while driving? For example, are there functions in the systems that increase mental workload in such degree that they should not be available while driving?

Like Barrow, the European Commission presents another restrictive usage possibility, allowing only certain people to use the system. The basic idea is requiring operators to be licensed to use the system. This would ensure proper training and awareness of potential hazards.

### 3.6 Earlier Navigation System Evaluations

Even though in-vehicle navigation systems are quite new products on the market, much research has been done on both existing systems and prototypes. Below some of the most recent studies are presented.

#### 3.6.1 Common Safety and Usability Problems

Even though there has been substantial research on in-vehicle navigation systems, many safety and usability problems re-occur in system after system, even in systems that have been evaluated from some sort of safety or usability point of view (Nowakowski et al. 2003).

Nowakowski and his colleagues (2003) describes usability studies made on four different navigation systems, two of them made for in-vehicle use, one reproduction prototype, and one handheld device with a software package. One common question among the users was: “What does this button do?” as buttons
with vague terms were frequently misinterpreted during usability testing. Different types of control location problems were also noticed. First, drivers noted that controls frequently used together were located far apart from each other. Second, drivers noted that buttons used for performing frequent or critical tasks while driving often were located with the furthest reaches.

Problems with button sensitivity seemed to vary with age. Often, button presses among the younger drivers were not registered (too low sensitivity), whereas the older drivers’ button presses registered as two or three key presses (too high sensitivity).

Progresses in the system, such as completing a step or saving changes were usually associated with forward movement using an “Enter” or an “Ok” button while leaving a screen using a “Back” or “Previous” button was associated with cancelling any changes that had been made. Consequently, users did not believe that changes were saved when they were required to exit a screen using a back, cancel or previous button. These problems were also combined with overall issues concerning how the menus were organized and how to find the different features in the system. An extra dialog box for example, can add up to two seconds on the destination entry time, since the driver must read the dialog box, decide, and then press the ok button.

As a conclusion, Nowakowski and his colleagues believe that heuristic evaluations are functional to quickly identify a large number of safety and usability problems in navigation systems since human factors experts and established design principles provide a basis for identifying the problems and recommending changes. To further reinforce information on the primary problems, the expert- and heuristic evaluations need to be followed up with user testing to expand the variety of problems found and find motivations for changes.

### 3.6.2 Evaluation Volvo XC90

In 2003 Volvo Cars Corporation made a usability evaluation on the Volvo XC90 navigation system. Several car owners were interviewed about their navigation systems (Larsson, 2003).

**Main Issues**

The main issues considering the XC90 navigation systems was that many drivers used only a small part of the system and were not aware of the systems abilities and
more advanced functions. Users believed that it was not clear how to use the system and that the system was inconsistent. They also believed that it was unclear whether to use the “Enter” or “Back” button to confirm choices made in the menu.

Complaints were also directed towards the large number of steps in the menu structure and many users had problems understanding the menu names and consequently also problems with foreseeing or remembering what functions that were hidden behind the names. Problems about the graphical symbols being ambiguous and hard to understand were also introduced together with issues finding out how to delete a destination selected in the menu.

The system’s feedback was experienced as being slow and users tended to tap the buttons twice to perform an action. This often led to double-clicking and consequently undesired actions made in the system.

When it came to the controls several users found the steering wheel control’s “Enter”-button to be wobbly and shaky, not giving the desired quality impression. Many people also had problems with physically distinguishing the “Back”- and “Enter” buttons. Critique was also directed towards the steering wheel feeling reversed and as a consequence of these problems together many drivers tend to rather use the remote control than steering wheel control when driving.

**Comments**
The interviewed users also had some positive critique with the system (especially the fundamental functions) being easy to learn. They also believed that quick menu was a good option and that the information presented on the display was sufficient, not making the display too cluttered. One negative comment on the quick menu though was the users found it unintuitive to use the “Enter” button to make it appear on the screen.

Other functions in the system that was found usable was that the system suggests full street addresses out of the entered letters when entering a destination and that the systems provides updated traffic information about e.g. accidents and road constructions.

**User Suggestions**
Besides the positive and negative feedback from the interviews users also came up with a number of suggestions that they thought could improve the system. One suggestion was the idea of having a touch screen but the users were also aware that
this could be a problem with the current location of the display. Moreover, several users wanted shortcuts to the most frequently used functions but did not like Volvos proposal of a Safemode that would narrow down the number of functions available while driving. A suggestion for learning the system was also presented as some users wanted to have a tutorial that show how to make different settings and adjustments in the system. One person suggested that keeping the “Back”-button pressed down immediately should bring the user back to the map screen. The same procedure was also suggested to work as a fast eraser of letters in the renaming-menu.

3.6.3 The J.D. Power Navigation Usage and Satisfaction Study
During the last six years J.D. Power and Associates have been evaluating the existing navigation systems on the market. The most recent study in 2004, involved 78 factory-installed systems. The trend from earlier studies was that the individual satisfaction attributes, system appearance and clarity of voice commands remained industry strengths, whereas ease of inputting a destination and understanding the controls continued to perform the weakest.

The navigation systems in Volvos cars, manufactured by Mitsubishi Electric remained consistent in both performance and quality since the last evaluation. Their performance in the areas of voice and system appearance was notable, but there is great need for improvement involving factors as consumer satisfaction. Mitsubishi was the only Japanese supplier that scored below the study average.

Panasonic (Mazda) was performing significantly better, on average, than all other suppliers in the study. Their strengths are in areas such as Ease of Use and Information Screen where they are outperforming the competition.

The first supplier to introduce a fully integrated and functional HMI in a vehicle was Siemens VDO with the BMW iDrive. They still need to provide a more user-friendly system, by for example offering alternative input methods such as touch-screen.

The Delphi systems that are available in GM vehicles were performing poorer than any of the systems in the study. One reason for this is the small screen sizes along with the inability to easily operate the system.
Denso (Cadillac, Toyota) had the highest customer satisfaction in the areas of Appearance and Speed of System. They also continue to develop a system that offers the user intuitive design and multi-functionality.

The Harman/Becker systems (Audi, Mercedes, Porsche etc.), were all located in the centre stack of the vehicle. Neither of the systems offered touch screen or voice control systems but their interface-work on the Audi MMI system was a good example of HMI integration. The systems still needs cleaner information screens though.

From the J.D. Powers analysis it is clear that the majority of vehicles having moved from buttons/knobs to touch screens are experiencing an increase in their customer satisfaction.

The Six Navigation Factors
One of the major outputs of the evaluation study was the way of depicting the relative importance the six navigation factors play in differentiating the good products from the poorer ones. These six and their percentage were:

- Ease of Use
- Routing
- System Appearance
- Speed of System
- Information Screen
- Voice Prompt

The factor of most importance was by far Ease of Use (Figure 7). The systems that have large touch screens that are easy to reach, have understandable controls and logical screen sequences rated highest on the Ease of
Use attribute. The Volvo XC90 scored below average in all satisfaction attributes except Understanding the controls and Understanding the use manual, see Figure 8.

<table>
<thead>
<tr>
<th>Satisfaction: Ease of Use</th>
<th>Rating</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Following Driving Directions</td>
<td>7.79</td>
<td>-0.29</td>
</tr>
<tr>
<td>The Order Information is presented on Screen</td>
<td>7.52</td>
<td>-0.15</td>
</tr>
<tr>
<td>Reaching Screen to Operate</td>
<td>7.45</td>
<td>-0.34</td>
</tr>
<tr>
<td>Understanding the Controls</td>
<td>7.10</td>
<td>0.20</td>
</tr>
<tr>
<td>Understanding User Manual Instructions</td>
<td>7.06</td>
<td>0.32</td>
</tr>
<tr>
<td>Inputting Destination</td>
<td>6.05</td>
<td>-0.23</td>
</tr>
<tr>
<td>Overall Satisfaction: Ease of Use</td>
<td>6.99</td>
<td>-0.25</td>
</tr>
</tbody>
</table>

Figure 8: Satisfaction Ease of Use (J.D. Power 2004)

Future Navigation Systems
According to the J.D. Power report, the majority of consumers want a system with touch screen controls and/or voice activation. Touch screens are viewed as easy to use and are preferred by the majority of consumers. Less than twenty percent prefers the system controls to be on the steering wheel and only nine percent would like a knob in the centre console, similar to the BMW iDrive.

3.6.4 Other Comments on the Systems
The Volvo navigation system is manoeuvred by a couple of buttons on the backside of the steering wheel. These are tricky to handle and it is hard to know in which direction the marker will move. Audi has come up with a new method for inputting. The drivers’ selects the letters and numbers with the help of a rotary knob. The system works fast and easy and is supreme in contrast to Volvo’s controls, Saab’s touch screen and BMW’s iDrive (Stjerna, 2004). Other disadvantages reported about the Volvo system include bad translations and abbreviations in the menus (Kroher, 2004).

3.7 System Evaluation and Testing
The interior of a car, for example, the interface between car and driver is indeed a central part in the automotive industry and different kinds of car interior design are praised and blamed by users every day. There are different methods for evaluating a user interface design and some of these methods are presented below.
3.7.1 Heuristic Evaluations

A heuristic evaluation is a method for finding usability problems in a user interface design by having a small number of evaluators examine the interface and form an opinion of its compliance with the recognized usability principles so called “heuristics” (Nielsen, 1992). To get the most out of these kinds of heuristic evaluations, Nielsen (1994) recommends to combine inspection reports from a set of independent evaluators and to summon these reports to form a list of usability problems.

One mistake that is often made today is that designers play the user’s role themselves. A designer is not the typical user but a kind of expert and although a small group of experts can find most of the major usability issues, some problems may remain (Hansson, 2001). There are several ways of evaluating a system. Two of these are expert- and heuristic evaluations, often used in combination (Nowakowski et al. 2003).

Heuristic evaluations usually provide the best results when carried out by 3 to 5 human factor experts. While a single evaluator typically is to find only 35 percent of the usability problems in a design, the combined results of 3 to 5 evaluators’ yields up to 75 percent of the usability problems. Therefore, as several studies have shown, methods using expert evaluators are able to find many usability problems that are overlooked by user testing, but user testing is also of importance as the users tend to find some issues that are overlooked by expert evaluators. This means that the best result often can be achieved by combining several methods (Nielsen, 1994).

Norman’s Design Principles

There are many ways of conceptualizing usability. One way is by using design principles that are obtained from a mix of theory-based knowledge, experience and common sense. A number of different principles have been promoted and the best known are those written by Donald Norman (1988) in his book *The Design of Everyday Things*. These principles include:

Visibility

The more visible functions are, the more likely are users to find out what to do next. When functions are not visible it makes them more difficult to locate and know how to use.
Feedback
Feedback is related to the concept of visibility and is about the user getting information back about what action has been done and what has been accomplished. There are various kinds of feedback in interaction design; audio, visual, tactile, verbal and different combinations of these. Using correct feedback can also provide the necessary visibility for user interaction.

Constraints
Constraining refers to determining ways of limiting the kind of user interaction that can take place in a given moment. An advantage with this kind of constraining form is that it avoids the user from selecting options that are incorrect and thereby reduces the risks of making mistakes.

Mapping
Mapping is a term meaning the relationship between two things; for example between controls and their movements and their results in the world. A natural relationship between the control and its function, called natural mapping, is to strive for.

Consistency
The term consistency refers to designing interfaces that have similar operations and uses similar elements to achieve similar tasks. One of the benefits with this consistency is that the interfaces are easier to learn and use. Another benefit of creating a consistent interface with categories of commands is that it can be mapped into subsets of operations instead of having different buttons for each function in the system.

Affordance
Affordance refers to an attribute of an object that allows people to know how it should be used; for example, a mouse button invites clicking. When the affordances of a physical object are perceptually evident it is simple to know how to interact with it.

Shneiderman’s “Golden Rules”
Shneiderman (2005) offers eight principles called the “golden rules” that can be applied during the design stages or as an evaluation tool afterwards in most interactive systems. These principles are derived from experience and, refined for over two decades so they need validation and tuning for specific design domains.
Shneiderman notes that this list of principles can not be complete but that it has been well received as a useful guide to designers.

**Strive for consistency.** Sequences of actions should be consistent in similar circumstances and identical terminology ought to be used for prompts, menus and help screens.

**Enable frequent users to use shortcuts.** Frequent users want shorter response time and that should be available. Response times can never be too fast for an experienced user and it is probably best to design a system to run as fast as possible even for the novices since they can still select how quickly they want to respond to the system.

**Offer informative feedback.** Every operator action the user performs should receive feedback. This feedback can be modest for a frequent or minor action and more substantial for more infrequent and major actions.

**Design dialogs to yield closure.** Like a good short story, actions should be organised to have a beginning, middle and an end. The feedback at the end permits closure to take place so that the user is free to move on to the next stage.

**Offer simple error handling.** The risk of error needs to be designed out of the system wherever possible. The system should offer the user a simple broad mechanism for handling errors, and commands that do not mean anything to the system should leave the system unchanged.

**Permit easy reversal of actions.** Actions should be reversible so that the user knows that errors can be undone. This way the user can explore the system without being afraid to make irreversible errors.

**Support internal locus of control.** Since experienced users like to know that they are in control of the system, users should initiate actions rather than being receiving actions from the system.

**Reduce short term memory load.** The display design should be simple and sufficient. Time training has to be allowed and multiple-page displays should be united. As a designer you must remember that the users have a limit to the amount of information they can hold in their thoughts.
Nielsen’s Ten Main Usability Principles
Jacob Nielsen offers ten main usability principles which are to be used as a part of an evaluation. These, as well as Norman’s and Shneiderman’s principles (heuristics) overlap each other but are all useful for analyzing and evaluating aspects on an interactive product (Preece et al. 2002).

1. **Visibility of system status.** Always keep the user informed about what is going on and provide appropriate feedback within reasonable time.

2. **Match between system and the real world.** Try to speak the users’ language by, instead of using system oriented terms, use words, phrases and concepts that are familiar to the user.

3. **User control and freedom.** Offer ways of allowing the user to easily escape from places they unexpectedly find themselves in, by using clearly marked “emergency exits”.

4. **Consistency and standards.** Avoid making users unsure of whether different words, situations or actions mean the same thing.

5. **Help users recognize, diagnose, and recover from errors.** Use basic language in describing the nature of a problem and suggest ways of solving it.

6. **Error prevention.** Prevent errors occurring in the first place (where possible).

7. **Recognition rather than recall.** Make objects, actions, and options visible to the user.

8. **Flexibility and efficiency of use.** Offer accelerators that are invisible to novice users, but allow more experienced users to carry out tasks faster.

9. **Aesthetic and minimalist design.** Avoid using information that is irrelevant or seldom needed.

10. **Help and documentation.** Supply the user with information that can easily be searched and provides help in a set of concrete steps that can simply be followed.
In the design and evaluation process for a product it is also important to consider international, national and brand requirements and recommendations within the area. Another important thing is to study the concurrent products and to identify the user’s requirements and desires for the product. During discussions, users can often come up with ideas for changes and modifications to improve the product and working situation because of their implicit knowledge of the product and its usability. This knowledge is positive and when correctly used in the concept-generation stage, simple alternative concepts can be created quickly (Hansson, 2001).

### 3.7.2 Cognitive Walkthroughs

One approach to heuristic evaluations for predicting users’ problems without doing user testing is by using walkthroughs. The method involves walking through a system task and noting problematic usability features. A cognitive walkthrough involves simulating a user’s problem-solving process when using a system and is often carried out by a single evaluator at a time (Nielsen, 1994).

According to Preece et al. (2002), the steps involved in cognitive walkthroughs are:

1. Identifying and documenting the typical user’s characteristics. Sample tasks focusing on the aspects of design to be evaluated are then to be developed. Also, a prototype of the interface is to be produced, along with sequences of actions needed for the user to complete the tasks.
2. A designer and one or several experts coming together to do the analysis.
3. The expert evaluators walking through the sequences for each task, placing it within a typical scenario context. While doing this, they should try answering the following questions:
   - Will the user know what to do?
   - Will the user see how to do it?
   - Will the user understand from the systems feedback if the action was carried out correctly or not?
4. As the walkthrough is being completed, a record of information is complied in which:
   - The theories of what would cause user problems and explaining why users would face these difficulties are presented.
   - Notes about smaller issues and design changes are made.
   - The results are summarized.
5. Then, the design is revised to correct the problems presented.
The strengths of this method are that they in detail focus on users’ problems without the users needed to be present (Preece et al. 2002).

### 3.7.3 Think Aloud Protocols

Another way of receiving knowledge that could be combined with cognitive walkthroughs is the use of *verbal protocol analysis*, also known as *think aloud protocols*, where users or experts are asked to “think aloud” as they are performing a task. By doing this, people say out loud everything that they are thinking and trying to do, and thereby their thoughts are externalized (Preece et al. 2002). This method is particularly useful in gathering information about users’ interaction processes, for example usability problems and different requirements that users might have when using a system (Obata et al. 1993).

### 3.7.4 Laboratory Testing

The most common usability evaluation methodology is *laboratory testing*. By using this method it is possible for the researcher to control the environment, the tasks, the interaction with the subject and many other factors that may confound the results. Laboratory testing can be effectively used throughout the design process to evaluate an existing product, prototypes, competitor products etc. The power of this testing method comes from controlling as many variables as possible and understanding the effects of those beyond control, meaning that this type of testing method, when done correctly, gives concrete and objective results (Barfield & Dingus, 1998).

### 3.7.5 The Lane Change Test (LCT)

Identifying the potential risks of a navigation system is difficult. One approach is to look at measures of potential such as lane variance (Green, 1997). A test often chosen for these kinds of experiments is the Lane Change Test (LCT), a test that quantitatively measures the degradation of performance due to distraction on a primary driving-like task while a secondary task (for example, operating a navigation system) is being performed. The LCT is intended to work as a tool, helping system designers to ensure that the planned benefits outweighs the risks of devices and features meant to be used while driving (ISO/WD, 2005).
The LCT – Simulation is a simple driving simulation, see Figure 9, requiring the test participant to drive the 3 lane LCT course at a constant speed of 60km/h. The speed is system controlled and can not be affected by the participant. Participants strive to maintain their position in the centre of the indicated lane. While driving forward, participants then encounter traffic signs, which prompt them to change lanes (ISO/WD, 2005).

**Lane Change Signs**

The lane change signs are visible at all times but blank until the lane instructions on the signs appear instantaneously at a distance of 40 m before the sign (Figure 10). The mean distance from sign to sign is 150 m and the presentation order of lane changes is randomised to avoid learning effects.

Each participant performs identical secondary tasks of equivalent difficulty but with different presentation order. Also, the order of the different tracks and the combinations of secondary tasks should be counterbalanced or randomised. The start and ending points of each secondary task operation is recorded, as well as driving performance during no task conditions for later data analysis (ISO/WD, 2005).

A LCT-test should be formulated as a within-group-design, meaning that all participants should do the same experiment. Both driving skills and performance in the LCT-study may vary between people but this is compensated as the test is being carried out with repeated measures. The advantages with this type of design are foremost the decreased influence of individual factors and the possibility to see the performance of different tracks for every contestant. To assure that the testing equipment really measures correctly it is important to calibrate the testing equipment regularly (Lundberg & Strålin, 2005).
Why the LCT?
As mentioned before, the LCT method is a simple laboratory method that measures performance degradation quantitatively. According to the ISO/WD (p: 30, 2005), this method is chosen from various alternatives because it:

• Has good face validity
• Reflects manual, visual and cognitive components of driving
• Contains elements important to the driving task:
  o Path following and manoeuvring
  o Event detection and vehicle control
• Discriminates between simple and complex tasks
• Is a replicable measurement method
• Can be used in most stages of product development and in production vehicles
4. Method

This chapter explains the methods used in the thesis. To investigate the safety and usability of the Volvo navigation system two research methods were combined. One was usability evaluation through heuristics; the other contained subjective quantitative user evaluations as well as quantitative laboratory testing. This method chapter will review how these evaluations were carried out and how the tests were designed and completed.

4.1 Usability Evaluation

To get a first user opinion about the existing Volvo navigation system (P1) some initial user studies were made. Five participants in the ages 23-26 were invited to take part in the study. The participants were students at the University of Linköping, all with an educational background in usability- and interaction design. The idea of using these independent experts was to; through their implicit knowledge of the product and its usability, receive suggestions for changes and modifications to improve the product. This type of design appraisal, described in the theoretical framework by Green & Jordan (1999), gives an insight that can not be provided by the designer alone.

In this first study, a working simulation of the P1 system was installed on a PC-laptop. The users were then to perform some exercises using the Arrow-keys, Enter and Shift-bar on the keyboard to navigate in the system. The exercises were divided into two common exercises that are frequently used in the current navigation system and seven more advanced exercises that require more steps in the menu hierarchy. The language installed on the simulator was Swedish. This was to avoid problems with the evaluators having different skills in English. One possible disadvantage of doing this was that poor translations from English to Swedish in the system could affect the evaluation of the Swedish system but perhaps not exist in the English version.
The users thoughts and opinions of the operations were collected through *think aloud protocols* at every stage. This method was used to give an early understanding by gathering as much information as possible on the users’ interaction processes, like usability problems and requirements that they might have when using the navigation system. As a complement to the *think aloud* part of the study some questions were asked based on a combination of design principles described by Shneiderman (2005) and Norman (1988). These principles were: *visibility, feedback, permitting easy reversal of actions, constraints, match between the system and the real world and aesthetic and minimalist design*. These design principles were selected on the basis of the information received from the initial think aloud protocols and are described in detail in chapter 5.1.

### 4.2 Usability and Level of Distraction Testing

The usability and level of distraction testing consisted of two quantitative parts. The first part was a simulated driving task to investigate the navigation systems level of distraction on the main task of driving. The second part was a questionnaire filled in by the participants, after driving the simulator, focusing on the system’s usability.

#### 4.2.1 The Lane Change Test (LCT)

A mentioned before, driving is to a high degree a visual task. Therefore everything that possibly distracts people from the primary task of driving with their eyes on the road and hands on the steering wheel has to be investigated with regard to safety considerations (Baumann et al. 2004). The method used to measure driver distraction in this study was a Lane Changing Test (LCT), described in the *theoretical framework*. These tests were conducted in the ergonomic laboratory at Volvo during five days in April 2005.

**Participants**

A total of twenty test persons (13 men and 7 women) in the ages between 24 and 48, with an average age of approximately 36 participated in the test.

**Criteria for Participating**

Each test person that was interested in participating in the experiment answered an e-mail inquiry that was sent out to some employees at Volvo Cars that had previously signed up as volunteers for the company’s experiments. They were asked to write down what day and time they were available to participate. A
schedule was then set up and the test persons received a confirmation e-mail with the exact time and location for the experiment. Due to Volvo security regulations all people that participate in these kinds of experiments have to be Volvo employees to be allowed to enter the restricted areas at Volvo Torslanda (Gothenburg).

Because of a quite limited access to test persons no considerations were made whether the participants had former experience of navigation systems or not, but when asked before starting the test it turned that out almost everyone had used the P1 system or similar systems at some occasion, since these systems are often installed in test- and company cars.

4.2.2 Material

Below, all the material used in the testing sessions is described.

Equipment

The car used for the experiment was a 2005 Volvo V50 equipped with a P1 navigation system (described in the Background chapter). The front wheels of the car were removed and the steering arm was loosened from the front part of the chassis and mounted to the LCT-equipment via a mechanical steering device, see Figure 11. A battery charger was also connected to insure that there would be no breakdown due to power failure.

A white theatre screen was placed in front of the car at distance of approximately one meter from the bumper (Figure 12). The distance was not pre-advised but came out natural as the picture presented on the screen was being optimized. To present the simulation on the screen a projector was placed on the roof of the car in an angle so that it would not cause reflections through the windshield.
Further, the mechanical steering device shown in figure 11 was connected to a computer and calibrated to optimize the steering wheel movement in the simulation. The steering was then continuously calibrated between every test person to assure that everyone would have identical conditions.

**Instructions**

Instructions on the test (Appendix A) were written down in advance as they were going to be orally presented to the participant. These instructions included information about the purpose of the test, ethical information of how personal information would be treated and on the test being voluntary.

**4.2.3 Pretest**

Before starting the tests, two pilot drives were completed to get a hint about the experiments complexity and to estimate the total experiment time. The testing was carried out by Volvo employees with former experience of Lane change testing. This was to assure that the equipment was correctly installed and calibrated. They also filled in and evaluated the questionnaire to assure that the questions asked were understandably formulated. The pretests lead to some grammatical changes and also some changes in letter size.

![Figure 12: Driver view](image)

**4.2.4 Procedure**

When coming to the ergonomic laboratory, the participants were first further introduced to what kind of experiment they had volunteered for. The initial information in the e-mail only revealed that it was a simulation study and not that it was concerning the navigation system. They were then informed that no interest was shown in their overall driving abilities but only in the amount of distraction that the secondary tasks would cause to the main task of driving.
Quantitative Distraction Testing

To start with the actual testing, the participants were invited to sit down in the car and adjust the seat and steering wheel into a comfortable position (Figure 13). When feeling ready, the test leader started a simulation on the screen (Figure 14). This way the participants could test-drive the system until they felt comfortable with it and felt familiar with the steering sensibility of the steering wheel and its corresponding feedback on the screen. These training tracks were not recorded or otherwise used in the study but immediately erased out of the system.

The participants were then informed that the test would consist of six tracks (simulations); the first a baseline with no distractions, the second to fifth with distractions and the sixth again a baseline with no distractions. After the opening test-driving participants were instructed to drive the first track just following the route directions on the screen.

When having completed the first track, the test leader informed the test persons of what exercises they were to carry out during driving. The navigation system was presented and the test leader orientated the test persons through the system exercise by exercise before starting the simulation to assure that the test person had understood the exercises and got a clue about how the system works. The participants were also informed that they did not have to remember each step in the exercises (since it was not a memory study) but would receive instructions/clues from the test leader during the simulation if so needed.
Control Procedures
The LCT-simulator consisted of a total of ten tracks and the six tracks that each of the test persons drove were randomly selected. The order of which the tracks were driven was also randomly chosen to avoid the possibility of a test person learning the signs from track to track.

Next, the participants were to drive four tracks using the navigation system. The study consisted of two different kinds of exercise categories; Common exercises and Advanced exercises (Appendix B). There was no former categorization of these exercises but there was an interest from Volvo in having an easy and an advanced mode in future navigation systems from a safety point of view; were the easy mode would consist of commonly used functions and the advanced mode consist of more complex functions. Therefore, the exercises used for the laboratory testing were selected in cooperation with Volvo to see whether or not the advanced exercises were to be more distracting than the common ones and thereby too distracting to be executed during driving.

The common category consisted of six exercises and the advanced of four exercises and the test persons were told to do as many exercises as possible but to primarily concentrate on the main task of driving.

To complete each exercise, a minimum number of button presses must be done, see Figure 15. These exercises were to be executed using a steering wheel control and a remote control, one at the time. Every test person was to use both of the devices (ten of them started with using the remote control and vice versa) and the order of which the exercises were carried out was that everyone started with the common exercise number one.

<table>
<thead>
<tr>
<th>Common</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise number</td>
<td>1  2  3  4  5  6</td>
</tr>
<tr>
<td>Number of Button Presses</td>
<td>24  10  4  4  5  26</td>
</tr>
</tbody>
</table>

*Figure 15: Minimum number of button presses needed to complete an exercise*

The reason for everyone starting with exercise one was that it involved inputting letters in the system, the most essential exercise in the navigation system. After doing exercise one, half of the test persons continued with number two, three etc. while half of them sustained with exercise six, five and so on. Regarding the advanced exercises, half of the persons started with exercise one and the other half with number four, all this to try to get the experiment as objective as possible.
All of the people participating in the experiment started with doing the common exercises and then doing the advanced ones. The reason for that was that the settings made in the advanced exercises are not (according to Volvo) supposed to be made by a complete novice user. The risk though, is the amount of training effect that can occur, but weighing the advantages and disadvantages of the situation, this was the best solution.

Logging Equipment
During each track the test leader logged the distraction measures during the different exercises. This logging was made with the help of a computer keyboard located just outside the driver’s door. The logging was started on each exercise when the test leader had finished his instructions and ended as the exercise was finished and the driver’s hands were back on the steering wheel. No logging was made on the parts of the track between two exercises.

After finishing the first two tracks, the test leader informed and showed the test persons the advanced exercises. The same logging procedure was made during the two advanced tracks and to finish of, another control track (only driving, no navigation) was run. This was made to later have the ability to get an average of the two control tracks and by that compensate the eventual training effects that might occur during the four exercise tracks.

Questionnaire
After completing the driving part of the test, each test person was asked to fill in a questionnaire (Appendix C) to evaluate the system. The scale on the questionnaire was 1 to 10 where 1 and 2 were considered very bad/hard and nine and ten considered very good/easy (a standard scale for Volvo). Some of the questions concerned the two different control types while others were more system related. The participants were also encouraged to write down personal comments on the controls and the system. The total test time was approximately forty-five minutes and during the test, candy and water was available to the test persons, allowing them to maintain their blood sugar and fluid level; all of this in accordance to conventional LCT-testing instructions.

4.2.5 Classifying the Material
After finishing all the test sessions, the logged data from each participant was stored in individual folders. The data was then summarized and averages of the different exercise categories were calculated. These calculations were used to get a
good measurement of the participants’ performance and the level of distraction for each track.

The questionnaires were also summarized and the total averages of the individual answers were calculated.
5 Results

This chapter presents the analysis from both the usability evaluation and the usability and level of distraction tests. The latter consists of two quantitative parts, a subjective questionnaire and a laboratory simulation.

5.1 Usability Evaluation

The usability evaluation made with a group of usability experts as evaluators gave some important results on usability problems in the system. The heuristics used for the evaluation were a combination of Norman’s design principles, Shneiderman’s “golden rules” and Nielsen’s usability principles (see 3.2.1).

Visibility: The more visible functions are, the more likely users will find out what to do next. When functions are not visible it makes them more difficult to locate and know how to use.

Feedback: Feedback is related to the concept of visibility and is about the user getting information back about what action has been done and what has been accomplished.

Permit easy reversal of actions: Actions should be reversible so that the user knows that errors can be undone.

Constraints: Constraining refers to determining ways of limiting the kind of user interaction that can take place in a given moment.

Consistency: The term consistency refers to designing interfaces that have similar operations and use similar elements to achieve similar tasks. A benefit is that creating a consistent interface with categories of commands that can be mapped into subsets of operations instead of having a button for each function in the system.
**Match between system and the real world:** Try to speak the users’ language by, instead of using system oriented terms, use words, phrases and concepts that are familiar to the user.

**Aesthetic and minimalist design:** Avoid using information that is irrelevant or seldom needed.

### 5.1.1 Identified Usability Problems

In the Expert evaluation, the following usability problems were found:

**Visibility**

One of the major usability issues that the evaluators found was the lack of intuitivism in the system. Several experts had problems in just finding the menus and many thought that the idea of reaching the quick menu through “Enter” was both unintuitive and impossible to predict. One person said: “How am I supposed to know that “Enter” reveals the quick menu?” Problems also occurred when the experts had difficulties finding different functions in the menus as they did not see the menu bar was scrollable.

Another problem due to the lack of visibility arose as the experts were to mark already selected street names in the “Itinerary” menu. This needs to be done in the system to be able to e.g. save them with personalized names. Criticism was also directed towards the erasing function when naming streets or facilities. Everyone was looking for an erase symbol in the display “keyboard” but did not find one. The idea of erasing existing letters by using the “Back”-button was not at all visible and one person commented that it felt “like an ad-hoc solution for missing to put an erase button on the screen keyboard”.

When told, the evaluators found the help texts that are visible in each menu. The general opinion was that these texts were too discretely presented and that the colour differentiation needed improvement. Another issue concerning colour was the fact that the text that shows the user which menu is currently active is written in blue on a black background.

**Feedback**

As only a PC-simulator was used for the evaluation no feedback issues concerning the different in-vehicle controls could be done. Questions on feedback were instead asked in the questionnaire following the simulation part of the LCT-testing.
The evaluators found several feedback problems in the system. One was that the system felt slow and this slow feedback on input sometimes lead to double clicking and thereby undesired commands in the system. Another problem was the lack of informative feedback when having selected an option. When one expert was to save a gas station as an itinerary he gets upset as no feedback is given whether the option has been saved or not. Similar problems also occurred for several of the others and the general opinion was that this had to do with the lack of consistency in the system as it is not clear what action that confirms a choice and what action that takes the user one step back in the menu structure. The overall opinions among the evaluators was that more informative feedback is needed to give the user clues of what function that has been carried out and that the feedback needs to be faster.

**Permit easy reversal of actions**
Combined with the lack of informative feedback, the evaluators found troubles with the ability to reverse actions. The problem of knowing what command that works as a confirmation in the different menus was also confusing as the user can have problems in knowing what actions that has or has not been saved. One example was when an evaluator selected “Clear itinerary” and got terrified when all the settings she had done suddenly disappeared. Besides that, she then had no idea of what settings that has been erased and she had to do everything all over again to be sure that all settings were recovered.

**Constraints**
The general question concerning constraints was whether or not to limit the functions available while driving. Several evaluators questioned the safety of using the system as a secondary task and comments like: “I would not try to do these things while driving” and “It feels dangerous to handle the system in traffic and I would perhaps only use the system as a regular map while driving” were common. One of the persons said that it might be possible to manage the system while driving but that it would require much training and that is negative when novice users should be able to use the system as well. One person pointed out that the system felt dangerous to handle in traffic and that he probably just would use the system as a regular map while driving.

To summarize, the majority of the evaluators thought that the system would be too demanding to interact with while driving and these opinions were thought of when it came to setting up the LCT and formulating the questionnaires used later in the study.
Among suggestions for increased safety the idea of blocking out some functions while the car is moving were presented e.g. that it could be a problem to type in the letters while driving and that voice control or touch screen could be wiser alternatives. Suggestions about being able to choose between a simple easy mode and a more advanced mode for more complex settings before driving away were also presented. These ideas agreed with the ideas presented by Volvo and were tested in the LCT.

**Consistency**

All evaluators had the same opinion about the navigation systems consistency, worthless! The primary consistency issue was the way the user is supposed to confirm choices in menus and how to enter different submenus. Sometimes the user should use the Enter key to confirm while other times make the choices by moving the control to the right (in this case pressing the “right-arrow”-key). In a third case the user is supposed to do a combination of first pressing right to chose an alternative and then confirming by pressing Enter. As an example one expert was to choose the gas station Statoil as a stopover but did not know how to confirm the choice and made the decision to do it all over again. Another said this about the system: “Why do I have to confirm with the Right-arrow when I have used “Enter” every time so far and why are there X:es as markers in this certain menu but not in other menus?”.

The different ways of navigating and making confirmations in the system made the evaluators unsure of what to do in different situations. As an example, pressing “Enter” in some menus like the “Route Options” menu does not confirm a choice but still makes the impression of doing this as the menu closes. When entering the menu again, the evaluators noticed that no choice had been made and that the only way to make a selection in this menu was through using the arrow keys to put a marker in an empty box. After putting this marker in place, “Enter” worked as a confirmation button. As one person put it: ”*The idea of putting a cross in the boxes is not intuitive. I want to make my choices by pressing Enter*”.

**Match between system and the real world**

Considering the question on matching the system’s words and symbols to the real world, the evaluators were of different opinions. Some of them found the menu-texts and symbols good and representative for the function they carried out while others found the texts and symbols more diffuse. One person said that he selected an alternative in a menu without really knowing what the function was. Another of the evaluators believed that poor translations between English and Swedish were a
Aesthetic and minimalist design
The general opinion about the aesthetic looks of the system was that it looked cheap and not at all as exclusive as it should, being a quite expensive option when buying a car. Comments like: “the system has to look more professional. It feels strange that such an expensive system looks like an early prototype” and “by improving the interface and get it to look more exclusive the users trust to the system would increase”. Besides this problem, the evaluators also found that the map felt cluttered with all the “Facilities”-symbols that are displayed on the screen. Further, instead of reaching the quick menu trough the “Enter”-button, the experts suggested that the menu should be visible at all time, since it does not take that much space in the display.

5.2 Lane Change Test and Questionnaire Results
In this chapter, the analysis made of the usability and LCT is presented. The analysis is of both a subjective and objective quantitative nature; the objective part is based on statistical calculations made on the data gathered during the LCT sessions and the subjective part based on the participants’ opinions and comments on the system gathered from the questionnaire handled out. The combination of these two analyses is to five a complete picture of the navigation system and the drivers’ interaction with it.

5.2.1 LCT
The main analysis of the test was the quantitative LCT and the results were conducted through ANOVA-testing.

Steering Wheel vs. Remote Control
The hypothesis formulated about the level of distraction was that there was a difference in how distracting the controls were to use while driving. The level of distraction was calculated by subtracting the average value of the two baseline tracks from the results of the tracks involving exercises. The LCT only provided data for all exercises in a track together, that is, no individual data for each exercise could be separated from the total amount of data logged for each track.
The acceptable level of distraction (according to Volvo’s recommendation) was a 0.5 meter deviation from the baseline. As seen in the table below (Figure 16), none of the exercises exceeded the acceptable standards:

<table>
<thead>
<tr>
<th>Type of Control</th>
<th>Average Level of Distraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steering Wheel</td>
<td>0.4439</td>
</tr>
<tr>
<td>Remote Control</td>
<td>0.4534</td>
</tr>
</tbody>
</table>

Figure 16: Total average level of distraction for each control

A test of within-subject contrasts was made and showed that there were no significant differences in the average level of distraction between the steering wheel and remote control neither on a common or advanced level.

**Common vs. Advanced Exercises**

After comparing the controls on the two levels, the common and advanced exercises were compared in a test of within-subject effects, that is, without including the two controls. No significant differences were however found between the common and advanced exercises, see Figure 17.

<table>
<thead>
<tr>
<th>Type of Control</th>
<th>Average Level of Distraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Steering Wheel</td>
<td>0.4986</td>
</tr>
<tr>
<td>Common Remote Control</td>
<td>0.4512</td>
</tr>
<tr>
<td>Advanced Steering Wheel</td>
<td>0.3891</td>
</tr>
<tr>
<td>Advanced Remote Control</td>
<td>0.4557</td>
</tr>
</tbody>
</table>

Figure 17: Total level of distraction for each control and type of exercise

**5.2.2 Questionnaire**

An analysis was made from the questionnaires that each test person completed after doing the simulation part of the test. First, the ten questions are presented (translated from Swedish to English by the author) followed by the users’ comments and ratings of the system. The questions were based on general usability heuristics completed with questions on safety, tactile coding and menu structure. The idea of this was to get feedback on questions concerning both the different controls and the system as a whole. Dependent two-tailed t-tests were then conducted to see if there were any significant differences the two controls. Below, the results from all questions are presented but statistic values are only presented in
questions were significant differences were found between the steering wheel- and remote control. The questions were:

1. *Feedback*: How well did you think that the system’s feedback responded on your commands?

2. *Restrictions*: How do you feel about limiting what functions that should be available while driving?

3. *Consistency*: How consistent did you experience that the controls functions were? (Did the control work in a similar way throughout the system?)

4. *Learning the controls*: How easy was it to learn the controls?

5. *Tactile coding*: How did you experience the tactile coding? (Were the sizes, shapes, inward/outward bends well designed?)

6. *Quality*: How was the quality feeling of the different controls?

7. *Learning the system*: How complicated did you think that it was to learn the system basics?

8. *Efficiency*: How efficient was it to carry out the exercises in the system?

9. *Safety*: How safe did it feel to do the exercises from a traffic safety point of view?

10. *Menu Structure*: How easy was it to find the intended functions in the menu structure?

**Scale**

The scale used was a 1-10 scale (Volvo standards) with 1-2 being rated *very bad/hard* and 9-10 *very good/easy*. The following tables show the participants’ average ratings on the different questions for both the steering wheel control and the remote control. General questions on the system as a whole are not comparable between the two controls and these results are therefore not presented graphically.

1. **Feedback**

   Overall, the participants found the system feedback to be reasonably good. Some comments on the system were made though:
• Ok, but not good.
• The system sometimes feels slow and the actions made with the controls does not get any response in the system.
• The symbol of the system loading is unclear. A yellow circle with orange pieces that is hardly visible in the top right corner.

2. Restrictions
People agreed that a need of restricting what functions that should be available in the system. There results showed that there was a significant difference between the two controls in how the participants’ felt about restricting the functions. They found restrictions more important when using the remote control than the steering wheel control, $t (16) = -2.3142, p<.05$. The results were based on answers from 17 of the participants as three persons left the question unanswered.

When considering the system as a whole, some comments were:

• Restrictions are necessary but the restriction level should be adjustable in the settings menu.
• If you know the system well, no restrictions are needed, but if you are a novice user, restrictions are absolutely needed.
• Restrictions are correct from a safety point of view but probably not appreciated by the customer.
• Only the passengers ought to be able to control the system while the vehicle is in motion.
• Restrictions may confuse the driver and make the system more hazardous.

3. Consistency
Results from the survey showed that the participants found the system consistency to be on an acceptable level:
• Sometimes “Enter” leads to the next level and sometimes “Back” does the same thing.
• Why sometimes use “Enter” to confirm and sometimes confirm by pressing the joystick to the right?
• When you are in the quick menu, “Back” means that you leave the menu. When you are not in a menu, pressing “Back” reveals the main menu.

4. Learning the controls
Learning the steering wheel system was easy according to the survey answers. The participants found it slightly harder to learn the remote control and felt that the “Enter”- and “Back” buttons should switch places to feel more natural and intuitive.
• The joystick does not do the work as the use of it results in too much clicking in the menus.
• The remote felt easier to use as you can “read” the
buttons while driving.
- The movement of the joystick feels reversed and not entirely natural and intuitive.

5. **Tactile coding**
One common thing commented by the participants was that the tactile differences between the Back- and Enter buttons on the steering wheel control were too small. Other comments were:
- It is hard to feel the buttons on the remote control as they are not arrow shaped etc.
- The remote control is too big.
- The steering wheel control is hard to reach with the fingers.

6. **Quality impression**
The overall comments on the quality impression of the two controls showed that people find the steering wheel control to appear robust and expensive, while the remote felt cheap and plastic. The results also showed that the participants’ quality impression of the steering wheel control was significantly higher than higher than impression of the remote control, \( t (19) = 3.6927, p <.05 \). Some comments were:
- The remote control is illogical and gives a cheap impression which is unacceptable for such an expensive system.
- The remote looks and feels like a low-cost toy.

7. **Learning the system**
The survey results indicated that the system was between the
levels “acceptable” and “easy” to learn.
- Much easier to learn than the BMW I-drive but not that obvious though.
- Complicated to learn the menu structure.

**8. Efficiency**
The level of how efficient the system was to use was between “acceptable” and “good”.
- Ok, but not as good as I want it to be.
- Good, as there are not too many options but many opportunities in the system.

**9. Safety**
The results on safety showed that the participants find the system unacceptable from a traffic safety point of view but that sufficient training with the system before starting to use it would make the journey safer. There was a significant difference between the two controls in how the participants felt about safety. The results showed that they found the steering wheel control more safe to use than the remote control, \( t (17) = 2.5792, p<.05 \).

Many of the test persons commented that they would never dare to do the exercises they did in the simulator in real time traffic.
- The better you know the system, the easier it is to use it while driving.
• It would be preferable with some kind of warning when trying to do too advanced settings while driving.
• It feels safer to do the tasks while driving a real car on the road than it does in a simulator.
• A head-up display or other ways to improve the ergonomics would be a good idea.
• My experience from driving in reality is much better than the one I got from driving the simulator.

10. Menu structure
The menu received complaints about its illogical structure causing irritation among many test persons.
• It is so hard to find the intended functions in the system as it offers no visual clues. I always have to search for the right alternatives, even after several trials.
• They system does not feel intuitive what so ever.
• The stress of the situation together with limited experience made it hard to find the intended functions.

Last, to see if there was a correlation between the driving performance and the estimated safety rating, the individual results from each test person were compared with their estimations on the safety of the system for both the steering wheel- and remote control. Measures of correlation between the average level of distraction for the controls and the estimated safety rating was done to see if there was any linear relationship between the two factors.

The results however, showed that there was little if any correlation between driving performance and safety rating of the controls (both steering wheel and remote).

5.3 Summary
When summarizing the findings from the expert usability evaluation and the questionnaires and it can be concluded that the system has many weaknesses that can be referred to usability heuristics as well as to the participants’ opinions and comments. From the level of distraction testing test it can be concluded that no significant differences were found neither between the different types of controls used to navigate in the system nor between the two different types of exercises performed by the participants.
Results from the questionnaire the participants answered after having done the LCT showed that they found both the steering wheel control and the remote control bad to use from a traffic safety point of view. Both controls though scored within limits of the acceptable level in the scale.

Below, a summary of the different findings is presented.

**Usability Evaluation**
- There is a lack of intuitivism in the system
- There is a lack of informative feedback
- The safety of using the system as a secondary task can be questioned
- It could be an good idea to block out some of the more advanced functions while driving
- The system has several consistency issues

**LCT Results**
- Both controls score within the acceptable level of driver distraction
- There are no significant differences in distraction between the steering wheel and remote control neither on a common or advanced level
- There are no significant differences in distraction between common and advanced exercises

**Questionnaire Results**
- The system feedback is good
- The idea of restricting functions available while driving is good
- The systems consistency is acceptable
- The steering wheel control was easier to learn
- The tactile differences between the Back- and Enter buttons on the steering wheel control are too small in size
- The system is between the levels “acceptable” and “easy” to learn
- The systems efficiency is between the levels “acceptable” and “good”
- The system is found unacceptable from a traffic safety point of view
- The menu structure is illogical
6 Method Discussion

This chapter consists of a discussion about the methods and materials used in the thesis.

6.1 Design

The study included both qualitative and quantitative data. The reason for this was that Volvo wanted evaluations of both the navigation system controls and general usability/safety issues in the system and this could not be retrieved only through one of the methods.

The number of participants was 20 and can perhaps be seen as too few, especially as only 18 of them were included in the study. The reason for this was that two persons performed better while being distracted by a secondary task than while driving the baseline with no distraction at all. This ought to have been a result of a technical failure with the equipment and therefore these two participants were excluded from the driving part of the LCT-test. Their opinions in the questionnaire however were included in the results as they have nothing to do with the quantitative measures of the driving performance.

Since Volvo does not put an age tag on the targeted users, it is hard to say if there is a need for doing further testing on older people but since increasing age effects our visual and motor characteristics this might be necessary, if not just to see if a higher age does matter in these kinds of experiments.

6.2 Expert Evaluation

When looking at the expert evaluation it could be possible that more usability problems would have been found if the evaluators were more experienced usability experts and not only students with educational background in usable systems etc. The evaluators’ lack of experience in evaluating navigation systems makes it
possible for some problems to pass by without being discovered. The lack of former experience may also have had a positive effect as problems discovered may have been overlooked by experienced evaluators too familiar with the system.

Perhaps other heuristics would have resulted in finding different usability problems than those found with the ones used this time. This could have affected the results and also the proposals on how to make the system more usable.

6.3 LCT Analysis

To start with, there were no problems with roof-effects during the test. To assure this, the number of exercises was tested through pilot studies and the results from the study showed that the test persons were not to complete all exercises in such short time that it would harm the results of the test. This also showed during the tests since the few test persons that completed all exercises all had approximately one sign left to follow before the end of the track.

The results showed that there were no significant distraction differences between using the steering wheel control and the remote control when using the navigation system. These results though, only show the level of distraction in a simulated environment. It can be assumed that the results could differ if doing the testing in a real traffic environment e.g. on a freeway. In these kinds of simulators there are no feedback from bumps in the road, other cars, wind sounds etc. These factors could have different effects on the two types of controls but these types of feedback were not possible to include in the LCT-simulator and thereby neither the effects they might have on the usage of the controls.

The fact that the majority of the LCT participants had former experience of the P1 (or similar) navigation systems do not necessary have to have a negative effect on the results. Since earlier studies show that many of the experienced drivers tend to prefer using the remote control while driving (see 3.6.2) it is interesting to see that the preferred usage of the remote control resulted in no significantly worse results than the steering wheel control. This contradicts to Volvo’s generally accepted theory that keeping “hands on the wheel” is optimal when interacting with the navigation system.

One problem with the LCT-test is that it provides no other than visual feedback. There is a possibility to use a motor sound while doing the test but the sound is monatomic and does not at all sound like an automobile engine. Also, since neither
the steering wheel nor the seat provide any force feedback it is hard to compare the simulator with driving a real car. A thought would be to allow shakings in the seat and steering wheel if the wheels of the car touch the verge of the road and also provide sound feedback to give the driver a more realistic driving experience.

Another possible solution towards a more realistic test would be to integrate the LCT software into a real car. When the car is then driven on a test track or a closed freeway, the computer will record differences in lane keeping, and (if the road is prepared with signs) also possibly lane changing.

6.4 Questionnaire Analysis

In retrospection, the quantitative is enough for evaluating the level of distraction between the two controls but because of Volvo’s interest in evaluating the system as a whole, the LCT was completed with a questionnaire. Besides, collecting just the quantitative data from the participants and not letting them express their thoughts about the system would perhaps leave the participants unsatisfied with the situation and moreover leave them with information on issues and improvements that could be useful when evaluating the system interface.

The questions selected were all chosen to get as much information as possible out of the questionnaire concerning both the two controls and the system as a whole. Perhaps it would have been more efficient to only ask questions related to the two controls but this was not possible due to the lack of information that would result in concerning the rest of the system interface. Also, using other heuristics would possibly have resulted in different types of problems being found and that would probably also have affected the results and design proposals in a different way.

Asking about former experience with the system orally was perhaps not the best way to receive information. It would have been better to include a question about experience in the questionnaire. If collected this way, it might have been more distinctive and consequently give clear statistical results on how former experience effects the overall performance but since former experience was not a variable in the test, this subjective form of receiving information worked out well.

6.5 Generalization

Since Volvo’s intended users of the system is quite abstract it is hard to judge whether the intended users were reached when recruiting Volvo employees.
Though, since almost all participants had been using Volvo’s P1 system (or at least similar ones) on previous occasions, many of them were within the intended segment of users. The fact that the participants were all Volvo employees could have influenced the results, perhaps not in the driving part but when it came to answering the questionnaire. People could give too positive or too negative grades to the system, depending on e.g. what department they are working in or if believing that a higher result would lead to faster modifications etc.

Also the generalization towards real driving could be discussed. As mentioned before in this chapter, there is a considerable difference between driving in a simulator and driving a car in real-time traffic. It is hard to predict though what variables in real driving that would have an effect to change the LCT results. Therefore it is important to see that the results are based on laboratory testing and that further testing in real-time traffic is necessary to see what variables that should be implemented in the LCT to make it more generable.
7 Discussion

This chapter contains a general discussion on the different results.

The aim of this thesis was to find out which one of the steering wheel control and remote control that is the most distracting to use, if the advanced exercises are more distracting to carry out than the common ones, and how to design the system so that it would be more usable and less distracting to use as a secondary task.

7.1 Usability Evaluation

The usability evaluation gave a valuable first understanding in how the system worked and what major usability problems that was present.

7.1.1 Identified Usability Problems

Below, the different usability problems are discussed from the heuristics used in the evaluation.

Visibility

The major usability problem found was the lack of intuitivism in the system. Problems like finding the menus could be overcome if e.g. the quick menu was visible at all time, since the more visible functions are, the more likely are users to find out what to do next (Norman, 1988).

Figure 26: Screendump of today’s “Map-mode”
One solution would be to have two boxes constantly visible on the screen (Figure 27) with texts in them showing what the “Enter” and “Back” buttons are doing in the “Map-mode”. By doing the functions more visible to the driver the system may appear more clear and intuitive to use, resulting in less errors made by the driver and thereby less visible workload when not needing to correct unnecessary errors.

The problems with making the quick menu visible at all time is of course the amount of display space that it would occupy. It will have to be a trade-off between the map size and the size of the list of functions visible in the menu. Thus there is a risk of cluttering, but one solution could be to push some data into the background, but still leaving enough for the user to reach if necessary (Woods et al. 2002). When looking at today’s “Map-mode” (Figure 26) it is easy to see that showing even more information on the screen would result in even more clutter. Therefore, the best solution would probably be to have the second alternative with boxes as clues for the driver in finding the intended menus and thereby reducing the problems of the driver not finding the significant data that he/she is looking for (Woods et al. 2002).

When looking at earlier research, Ware (2004) talks about the importance of improving the user interface to tighten the loop between the user and the system, making it easier to obtain essential information through the display. By making the system more visible and thereby shortening the amount of time it takes to select pieces of information, the cognitive workload decreases. A solution with using boxes as clues for the driver could reduce the time needed to find the intended function and thereby also tighten the loop between the user and the system.

This way of designing information also agrees with the European Commissions principles (presented in Stevens, 2000) on visual displayed information by making it easier for the user to understand the system with a few glances that are short enough to not affect driving in a negative way. Designing a system that not at all affects driving negatively is probably a utopia as adding a secondary task does produce some amount of visual workload that might affect driving negatively (Janssen et al. 1999; Barrow, 1991; Burnett & Joyner, 1993; Nilsson et al. 1998; Moldenhauer & McCrickard, 2003; Harbluk & Noy, 2002; Alpern & Minardo,
2003; Little, 1997). However, by making future systems more usable, the amount of workload demanded from the systems may decrease, leading to fewer glances towards the display and hopefully safer driving.

If looking further on a solution of having boxes with written text, questions on cultural differences and language skills arise. These cultural differences and differences in language skills could be a potential problem but it is also possible that the words “Enter” and “Back” (that are written on the controls’ buttons) are to be more related to the concepts quick menu and main menu rather than to the semantic meaning of the words (Barfield & Dingus, 1998). These words are perhaps also more familiar to the user from than more complex system orientated terms would be and this is good if wanting to have a good match between the system and the real world (Preece et al. 2002).

Another problem due to the lack of visibility was that the evaluators had to mark already selected names in the “Itinerary” menu to be able to e.g. save them with personalized names. A solution to this could be to have arrows showing in which directions the marker can be moved and thereby making it more visible for the user to see where the functions available are located, see Figure 28. These recommendations are based on Norman’s (1988) design principle on visibility.

There was also criticism towards the erasing function when for example wanting to erase Street names or names of facilities. Since every evaluator was looking for an erase button on the virtual keyboard it would be a good idea to integrate a button marked like e.g. a computer keyboard button on the screen, see Figure 29, and to erase letters by marking the button and pressing “Enter”.

![Figure 28: Design proposal: Visual clues](image)

![Figure 29: Design proposal: Erase-button](image)
This function could be complemented with the non-visual functions of erasing using the “Back” button and pressing down the button for a longer time, resulting in erasing the entire word at the same time. These non-visual functions are not useful for novice users but is a shortcut that allows more experienced users to interact with the system more efficiently (Preece et al. 2002).

**Feedback**
The major feedback problem was that the system felt slow, resulting in double-clicking and thereby undesired commands in the system. These opinions also support the earlier results shown by Larsson (2003). If it is impossible to make the system any faster, the user needs better feedback on, for example that the system is loading and not receivable for input. These ways of informing the user of the system’s status increases the usability and reduces the eventual frustration that can occur when the user does not know the status of the system (Preece et al. 2002). The current navigation system has a symbol visible in the upper right corner when the system is loading (Figure 30) but this symbol is small and the current design of using an orange colour on a yellow background has to be changed to some more contrasting colours, making it easier for the driver to see the status of the system.

Another issue was the lack of informative feedback. The evaluators had problems knowing what actions that had been saved or not and together with the lack of consistency in the system as it is not clear what actions that confirm a choice and what actions only takes the user one step back in the menu structure. Using audible feedback to confirm saved actions could be one way of improving the system (Norman, 1988; Jordan, 2000). This way the driver can make an action in the system and then return focusing on the main task of driving. When the system is done saving data, it could give away a confirming sound, telling the driver that the input was processed successfully. This should be combined with visual informative feedback to show the user what action has been done and what has been accomplished.

Figure 30: Today’s system loading symbol
However, the sound volume should be adjustable and the whole function optional as this kind of sound also may be considered as an unnecessary feedback for more experienced users (Shneiderman, 2005). One idea can be to have “Informative Feedback” as a default option in the system but also allow the user to choose whether or not to use the option in the settings menu.

**Permit easy reversal of actions**

Together with the informative feedback, the evaluators found problems with the ability to reverse actions made in the system. The ability to reverse actions is very important to make the user feel secure and not afraid to make irreversible errors (Shneiderman, 2005). There is a problem in the current system as there is no confirmation demand needed for example when pressing “Clear itinerary”. This command can be selected by mistake, (due to slow feedback) and it can therefore be an idea, having the system ask a question if the driver really wants to clear the itinerary. This type of visual feedback may be distracting for a novice driver but maybe not as distracting as having to do the settings all over again. The feedback should be shown in a way so that it is easily dealt with, for example by having a text asking “Clear itinerary?” when having selected that alternative. If the user wants to clear the itinerary he/she simple presses “Enter” again to continue with the selected action. This way a frequent user can double-click the “Enter”-button without looking at the screen and not having to carry out too many extra steps that may frustrate the user (Preece et al. 2002). Another way of designing for the more frequent users is to make this kind of informative feedback optional to get a faster pace in the interaction (Shneiderman, 2005).

**Constraints**

The general question concerning system constraints was whether or not to limit the functions available while driving. According earlier research by Tijerina et al. (1998) and ElBoghdady (2000) entering a destination while driving is too distracting to be carried out in a safe way. The function of entering a destination was considered a common function by Volvo and therefore placed among the six common exercises executed in the LCT. The earlier research however, contradicts with the results from the LCT where the common exercises (including destination entry) distraction level was within the safety limit. This topic is discussed further in the LCT part of the chapter.

**Consistency**

One of the benefits with having a consistent system is that the interfaces are easier to learn and use (Norman, 1988). The evaluators were all discontented with the
navigation system’s consistency, primarily with the way the user has to change the way making confirming choices in the menus. This consistency problem support earlier research made on the Volvo navigation system (Larsson, 2003) and can lead to wrong choices in the menus, thereby requiring unnecessary extra attention from the driver when having to correct the mistake. By keeping the confirmation function consistent with one single action and thereby making it a standard, errors can be prevented from happening in the first place (Preece et al. 2002).

The recommendation of action to confirm a choice presented here is by using the “Enter” button. In today’s system some menu options require confirmation by moving the joystick (see Figure 4 in chapter 2.3) to the right. This may not be necessary and a better suggestion would be to use the joystick when choosing between multiple choices (were required) and then confirming the choices by pressing “Enter”. Also, to further simplify for the user, a solution with a clickable joystick is presented, see Figure 31.

The idea with making this change is to reduce the number of buttons and the number of fingers that must be used to control the system. According to Barfield & Dingus (1998) a “blind” control (such as this one) should the shape-coded so that the user can easily identify them by feel. This is also one reason for choosing an alternative with only one “Back” button and with a clickable joystick. It would make it easier for the user to feel the controls and therefore reducing the risks of error.

By using the same concept as Volvo’s earlier systems, with a “Back”- and “Enter” function, the new looks and feels of the system will not affect frequent users of the earlier versions negatively since the concepts being presented to the user are similar
to the previous device. By using similar concepts as earlier devices, the users will quickly adapt to a different appearance (Murphy, 2002).

Roessger (2000) suggests that switches and knobs should provide the user with haptic feedback to minimize the visual load. This can be achieved with this type of control since the “Enter”-joystick has multiple functions. According to Barfield & Dingus (1998), the navigation system should present menu selections only for currently available actions. This theory could be used when looking at possible design solutions. If e.g. there are only a few options available in the menu, the joystick can be “locked” from movement in one or several directions. If there is only one single option available the joystick can be totally locked and only clickable as an “Enter”-button. This way the driver can physically feel if there are any other options in the menu without having to put too much visual attention on the screen and thereby reduce visual workload.

**Match between the system and the real world**

Since some of the evaluators found the Menu-texts and symbols good and representative for the function they carry out while others did not, there can be no direct suggestions on improvements of the system design when it comes to matching the system and the real world. However, this is an interesting area and single opinions from the evaluators on poor translations and bad menu-names should be used to design future evaluations of the system from this point of view, especially since these problems has been known since earlier evaluations (Larsson, 2003).

**Aesthetic and minimalist design**

The expert opinions about the aesthetic looks of the system should be of great interest for Volvo as the quality look of the system was widely criticised. According to Marcus (2004), keeping the design simple can help increase the clarity and also the driver’s confidence. As the evaluators noted, an improved, cleaner, and more exclusive looking interface, might increase the users trust towards the system and
thereby also increase the tolerability towards occasional errors that might occur when using the system.

Another problem found by the evaluators was the feeling of the map being cluttered with all the “Facilities”-symbols that are apparent on the screen (Figure 32). These symbols are always visible on the screen and a solution to this cluttering problem would be to highlight the most important features like the name of the current road that the driver is on and placing the less vital information into the background (Facilities-symbols etc.). A method for doing this is by highlighting with the help of colours and studies have shown that this method results in quicker and more accurate recognition of targets in visual displays (Barfield & Dingus, 1998). By shortening the time it takes to select pieces of information from the system the cognitive load decreases (Ware, 2004).

In this case where the colours are to be perceived under conditions of glare and changing light failures will be more common than with constant lighting (Wickens & Hollands, 2000). Therefore it is of importance to use the same colour-coding rules throughout the system and to use colours that are distinguishable and not confusing.

**Validity**
All results from the expert evaluations were received without the evaluators actually sitting in a car. Therefore the results cannot be used when evaluating and discussing the two controls. Though, the usability problems found by the evaluators were used as a base for the questions asked in the questionnaire. Also, the problems found in this evaluation would probably not have been found by the participants of the LCT test and are for these reasons valid results when discussing redesigns and future research.

### 7.2 Usability and Level of Distraction Testing
The design of the current navigation system interface can be seen as a distraction variable that is not controllable. It can be assumed though that this variable did not affect the test as the interface was identical for both controls and held constant.

Even though the controls are physically diverse and located far from each other the way of interacting with the system is similar. Both controls have an “Enter”- and “Back” button and are manoeuvred in four directions using a joystick or a four-way switch. These similarities in interacting with the system makes the study more valid
than it would be with two different concepts of navigating the system since the LCT shows differences between the controls and their location instead of testing only the concept of navigation that they represent.

7.2.1 LCT

Steering Wheel vs. Remote Control
The results concluded that there are no significant differences in distraction between using the steering wheel control and remote control. These results are inconsistent with Volvos’ philosophy that the steering wheel control should be used by the driver from a safety point of view and that the remote control only should be used by a passenger, or by the driver when parked.

It is important to notice that this study was made on the current systems used in several of Volvos car models and not in future prototypes, meaning that the results should be of instant interest for the company. The results of this study make it possible to question if the steering wheel control is the way of interacting with the system in the future or if there are other alternatives to prefer.

Barfield and Dingus (1998), notes that one important aspect in designing navigation systems is the location of the controls. The further away the controls are from the driver, the greater resources are needed to activate the control. They therefore argue that controls located around the steering wheel or otherwise in close proximity of the driver are easier to use. If comparing their thoughts with the research from Alpern & Minardo (2003) and Somervell et al. (2002) the conclusion would be that; the closer to the driver the controls are, the more usable and more safe are they and by that less attention requiring and time consuming than controls located further away from the driver.

These results are interesting to compare with the results from the LCT study as there were no significant difference in the amount of distraction between the steering wheel control and the remote control. According to the earlier research the location of the steering wheel control ought to be the optimal location for a safe interaction with the system. Why is it then that there were no differences in distraction between the two types of controls? One answer could be that the remote control is even physically closer to the driver as he/she is holding the remote in the hand at a closer distance than when using the steering wheel control. If this is the reason there is no reason not to use the remote control while driving from a driver distraction of view. It is of course important though to include other possible
problems with using a remote while driving like e.g. having to put it down while changing gears.

Changes in the interface might affect the two controls differently and it is therefore important to further test the system after doing the suggested improvements, even if some of them are more concentrated on the display. Improvements made in e.g. the menu structure might facilitate the interaction more when using the remote control or vice versa.

**Common vs. Advanced Exercises**

The results from the LCT showed that there were no significant differences between the common- and advanced exercises. These results are extra interesting since the different exercises were categorized in cooperation with Volvo. Earlier research on in-vehicle navigation systems has concerned human-interface interaction were the most fundamental problem of driving overload (Smiley, 1989). A study by Tsimhoni & Green (2001) showed that adding a secondary task significantly degraded driving performance and to deal with this problem, Marcus (2004) points out that one way of reducing the interference between driving and secondary tasks is by limiting the functions available to the driver while driving. The results from the LCT show that in the case of Volvo’s navigation system, this reduction is not necessarily needed. One reason for this could be that the difference between the different categories was too petite. The common exercises may not have been as hard to find in the system’s structure but may instead have consisted of lengthier completion times and thereby more glances away from the road.

Since there are several ways of navigating in the system, the numbers of button presses presented in the method chapter are the minimum amount needed to complete the different exercises. The number of presses in the exercises varied considerably, 4 to 26 for the common and 4 to 39 for the advanced. As the LCT is not able to give separate data for each exercise in a track there is no possibility to see what separate exercises that were the most distracting. This is a clear disadvantage but since earlier research show that lengthier completion times, longer eyes-of-road time and more frequent glances to the display are causes of distraction (Tijerina et al. 1998; ElBoghdady, 2000) it can be assumed that exercises demanding thirty-nine button presses are more distracting than those demanding only four. Therefore it would be interesting to have further research done on each exercise individually, to see whether it is the number of button presses, number of levels in the menu structure or something else that affects the level of driver distraction.
Validity
When looking at the results, it must come to a discussion whether the LCT is a valid testing method or not. The fact that neither one of the four different driving-exercises exceeded the 0.5m limit recommended by Volvo can be compared with the level of experienced safety estimated by the participants.

The most distracting exercise (common steering wheel) had a lane deviation of 0.4986m. Several studies have shows that entering a destination while driving is too distracting to be carried out in a safe way (Tijerina et al. 1998; ElBoghdady, 2000). The result of this study contradict with these earlier results and instead show an acceptable level of distraction while entering a destination and other exercises involved in the usage of a navigation system. One explanation of the results in this study could be the number of tasks competing for attention. Since the simulator tracks consisted of roads without curves or other traffic, driving was probably a relatively uncomplicated task and the participants may have been able to handle a number of items competing for attention. Results by Green (1993) show that driving tasks may cause an unacceptable amount of workload if the driving task is essentially difficult e.g. driving on a curvy road. Therefore, the results may have been different if the LCT consisted of more complex driving situation with other traffic and curvier roads. Since the remote control is a handheld device, steering may have been affected differently if having to handle turns and overtaking other vehicles on the screen while trying to enter a destination in the system.

7.2.2 Questionnaire
These results becomes extra interesting when looking at the participants opinions on safety, gathered from the post-driving questionnaire, as both controls were rated worse than the acceptable level of safety. Many participants talked about never wanting to interact with the system while driving since they did not believe they had good control over the main task of driving.

Feedback
Opposite to the expert evaluation, the participants in the LCT found the feedback to be good. Although, some of the problems found by the expert evaluators were also noted here. Several participants had comments on the system sometimes feeling slow and responding late to actions made. The fact that these problems were being noted in both the evaluation and the questionnaire makes an improvement necessary. Another problem presented by both experts and LCT-test persons was that the symbol of the system loading is unclear. There is a need for improvement
and one way of making the system status more visible for the user is by changing the colours of the symbol into two more contrasting colours than yellow and orange. By using the two contrasting colours yellow and blue, see Figure 33, the symbol will also distinguishable for colour-blind people (Ware, 2004). A design solution for a symbol is presented in Figure 34.

**Restrictions**

People thought that there was a need for limiting the functions available while driving and some suggested that these restrictions should be adjustable in the settings menu. Others however talked about restrictions as being correct from a safety point of view but probably not appreciated by the user. Single participants even talked about restrictions as possibly confusing, making the system more hazardous.

When comparing these results from the questionnaire with the results from the LCT it can be discussed whether or not there is a need for limiting some functions available to the driver while driving. Since there were no significant differences between the common and advanced exercises restricting the system would be a wrong decision to make without any further research.

Another way of reducing the interference between driving and secondary tasks is by limiting the functions available to the driver while driving. The functionality of in-vehicle systems should be limited to tasks that do not significantly interfere with the driving task, functions that have benefits that outweigh the cost of including the function in the system, and functions that will be used frequently (Marcus, 2004).
Volvo’s interest in having a safe- and advanced mode in the system could be positive when looking at driver workload, and even if the amount of distraction that the interaction with the system is causing is within the accepted safety limits more research on restrictions should be done.

Since our human capacity is limited, the results of exceeding the limits are that people make mistakes and occasionally have accidents. According to Smiley (1989), when drivers become overloaded, they begin to neglect some of the information sources (like the rear-view mirrors) and miss information about other traffic.

If creating a more usable system, with restrictions based not on the complexity of the task that is to be carried out, but rather on the surrounding traffic, lighting conditions, weather etc. the amount of workload can be decreased.

Roessger (2002); Barrow (1991) and Chiang (2004) talks about people only having limited visual and mental capacities that are obtainable for secondary tasks. Whether or not this will lead to an overload is according to Green (1993) depending on the number of tasks competing for attention and the status of the surrounding environment. If designing a system less cognitively demanding, more attention can be directed towards the main task of driving and thereby reducing the risks of neglecting information from the surrounding traffic environment. This theory is supported by Alpern & Minardo (2003) and Somervell et al. (2002) who’s research has shown that putting more effort in designing a usable system as a well defined secondary task makes the system safer by requiring less attention and being less time consuming.

**Consistency**
Results from the questionnaire on the systems consistency agrees with much of the results from the expert evaluation. The participants in the LCT also had problems with how to confirm choices in the system, whether to use the “Enter” button or to move the joystick to the right. The design solutions for this problem are presented under the headline **Consistency** in the expert evaluation discussion (7.1.2).

**Learning the controls**
The participants found the controls quite easy to learn as both controls scored above average in the questionnaire. One of the few negative things about the steering wheel control was that its movement felt reversed and not entirely intuitive to use. Since the control is located on the back side of the steering wheel it can be a
problem for novice users not used to manoeuvring the system. One way of dealing with this problem could be allowing the user to reverse the joystick movement by changing the default settings of the system and thereby have better movement compatibility (Wickens & Hollands (2000)).

When giving their opinions on the remote control, many found it strange that the “Enter” button was located to the left and the “Back” button to the right. The participants thought that they would find it more intuitive having the confirmation-button located to the right. Since the majority of the people participating in the LCT found a solution with the “Enter” button to the right, this is suggested in Figure 35. By changing the location of the two buttons the consistency also increases as “Enter” would work as a power switch to turn the system on and off, something that is done by using the “Back” button in today’s system.

One other advantage that several participants found with using the remote control was that it felt easier to use as the driver can “read” the buttons while driving. This visibility advantage (compared to the steering wheel control) can help drivers to a faster interaction with the system as it reduces the time needed to find the intended button. To get a “blind control” like the steering wheel control more usable from this aspect there is a need to shape-code the control in a way that the user easily can identify it by feel (Barfield & Dingus, 1998).

**Tactile coding**

Opinions on the two controls tactile coding were almost solely about the almost nonexistent tactile differences between the “Enter”- and “Back”- buttons on the
steering wheel control. This problem was already pointed out by Larsson (2003) and it should therefore be of great interest for Volvo to change the appearance of these buttons in order to increase the tactile differences between them and thereby facilitate the users’ interaction with the system. This could be done by changing the texture and size of the “Back” button. If using the proposed design solution with a clickable joystick, working as both navigating tool and “Enter” button the “Back” button’s size could be enlarged and thereby more easily recognized.

Comments about the remote control being too big were also presented. Since Volvo’s intention was to not use the remote while driving, little effort has probably been put on designing the remote for this purpose. However, since the results of this study show that there is no significantly larger distraction when using the remote and therefore it should be taken into consideration of how to make the control more usable. One way is by optimizing the size, making it easier to hold while steering the car and to make buttons easier to feel and distinguish. However, no research has been done in this study of how to design in-vehicle remote controls and therefore this question is open for further investigation in future studies.

**Quality impression**

Overall comments on the quality impression of the two controls showed that the participants find the steering wheel to appear robust and expensive while the remote control felt cheap and plastic. The positive results on the steering wheel control are good to have in mind when designing new improvements to the control and give the manufacturer an understanding of what kind of design and material to use when wanting to give a robust, quality expression. The negative critique on the remote control though, does not boost the overall quality feeling of the system and since navigation systems are relatively expensive options in a car, the experienced quality feeling ought to be important in winning the customers’ confidence.

**Learning the system**

Results indicated that people find the system quite easy to learn but that learning the menu structure can be complicated. The question of how the menu structure can be improved lies in the other improvements needed to be done. If reducing the number of usability problems found in both the expert evaluation and the questionnaire chances are good that the menu structure will be more intuitive. The menu structure will be discussed further later on in this chapter.

If comparing the results from this study with the results from the evaluation made Larsson (2003) comments from the users show that learning the system is quite
easy but not as easy as some wanted. One way of solving this problem would be by using animated tutorials, showing the user how to interact with the system. Shneiderman (2005) points out that research has shown that animated demonstrations are more effective at describing the use of a system than static explanations like an instruction book. Earlier studies also show that users are faster and more accurate in performing tasks after being showed an animated tutorial than when been reading a textual explanation and this should be a good reason to use this kind of system explanation from a traffic safety point of view. However, Palmiter and Elkerton mentions (according to Shneiderman, 2005) that the positive effects on time and performance is reversed after some time and therefore recommends that tutorials should be reinforced with textual explanations like an instruction book.

When looking at this research it could be a good idea to offer animated tutorials of at least the most fundamental functions in the navigation systems. Because of its initial capacity of showing the users how to interact with the system it would be a good first introduction before starting to use the system, especially for people who are to use the system temporary, e.g. rental- and business-cars. For those users selecting the system as an option when buying a car, a tutorial would be an appropriate initial introduction to the system, but seen more as a complement to the instruction book. By showing only the most fundamental functions in the tutorial, the animation would not take too long time to watch. If wanting to know more detailed information about the system, the user can find this in the instruction book.

One way of demonstrating how to use a system is by using animated demonstrations that have been shown being more effective at describing the use of a system than static explanations such as an instruction book. Moreover, studies have shown users to be faster and more accurate in performing tasks after being showed an animated demonstration than when been reading a textual explanation. However, research has shown that the positive effect on time and error was reversed after some time, showing the limitations of using animations as a teaching tool. Researchers therefore suggest that tutorials should be reinforced with textual explanations like instruction books (Shneiderman, 2005).

**Efficiency**
The participants found the system’s level of efficiency to be on a level between acceptable and good but comments also showed that there was room for improvements to make it more efficient. Shneiderman (2005), talks about knowing the user and understanding that different users have different requirements and
attitudes towards technology. He divides the users into three groups depending on earlier experience with the system. By taking these different types of users in consideration when designing a navigation system Volvo might get a larger target group and a more flexible system.

To make a system usable for novice users, Shneiderman proposes informative feedback that may help the user know what action that has been done and what the outcome was. To help more intermittent users, orderly structure in the menus, consistent terminology and consistent sequences of actions is recommended. Expert users that want to interact rapidly with the system should be provided with brief feedback as informative feedback may be redundant. As noticed, all of these factors are discussed earlier and it is important to notice that designing for efficiency requires an overall good usability in the rest of the system.

Safety
According to the LCT results, the navigation system was safe to use as a secondary task. However, the results from the questionnaire showed that the participants found the unacceptable from a traffic safety point of view.

Menu structure
One major menu issue was that the participants had trouble finding the intended functions in the system and that this was irritating. Barfield & Dingus (1998) points out that there are cognitive characteristics that influence driver behaviour and that one of these is about perceptual and motor limitations that affect the driver’s information access. They suggest that limiting the information available to the driver could be a solution to the problem and by using the highlighting-technique (discussed in 7.1.2) this can be possibly be achieved.

It is important though to understand that there are several other factors involved in improving the menu structure and that the highlighting method might be of no value unless other improvements are made on factors like consistency etc. When looking at some participant comments on problems with visibility, lack of informative feedback and lack of intuitivism in the system, it becomes even clearer that the overall usability of the PI navigation system is a question of designing the system as a whole, since overlooking one part might affect the entire system holistically.

Validity
Many of the test persons made it clear that they would never dare to do the exercises while driving in real traffic. This is interesting in two aspects. First, is the
LCT a valid testing method (discussed in 6.3) and secondly, is the level-of-distraction results received from laboratory testing methods such as the LCT more valid than the subjective distraction experienced and commented by the participants of the study?

According to Nowakowski et al. (2003) expert- and heuristic evaluations need to be followed up with user testing to expand the variety of problems found and find motivation for changes. Testing the users both objectively in the LCT and getting their subjective opinions should be a good way to receive as much information as possible. Comparing these results with the information gathered from the expert evaluations should provide sufficient results, motivating changes in the system. As a conclusion, Nowakowski and his colleagues believe that heuristic evaluations are functional to quickly identify a large number of safety and usability problems in navigation systems since human factors experts and established design principles provide a basis for identifying the problems and recommending changes. To further reinforce information on the primary problems, the expert- and heuristic evaluations need to be followed up with user testing to expand the variety of problems noted and find motivations for changes.

The information received from the questionnaire can be seen as a supplement to the LCT as the participants’ opinions are based on the driving simulator. Because of this there is a possibility that the opinions depend too much on the participants believed performance in the LCT, and factors like e.g. aggression might affect their estimations.
8 Future Research and Conclusion

This chapter contains suggestions on future research on both the P1 navigation system and the LCT as a testing method as well as the conclusion of this thesis.

8.1 Future Work

When looking at the P1 navigation system there is still much improvement to be done regarding the usability. This thesis gives results on distraction testing and suggestions on how to increase the systems usability but further research will be needed to go even deeper into the different parts of the system to explore all aspects of it.

The proposals for redesign in this thesis are seen to solve most of the usability problems but further user studies need to be performed in order to investigate how the users experience the changes made to the system and if even more changes need to be done.

Suggestions that have been made on improvements on the system can perhaps result in differences between the two types of controls but it is too early to talk about these eventual effects before a new system actually has been implemented.

More research also need to be done on the design of the remote control. The results from this thesis show that it is not more distracting to use the remote while driving. Volvo however, had probably not put too much thinking in designing a remote that is to be usable while driving. Therefore it would be very interesting to see what possible differences in the LCT a redesigned remote control would lead to.

The LCT is a tool for measuring distraction but research has shown that cognitive demands may or may not correspond with performance. This could mean that the LCT might or might not measure workload as well. According to Wickens &
Hollands (2000), the workload criterion is the only satisfying criterion when it comes to selecting between different alternatives.

Therefore, further research on the subject needs to be done to assure that the results on distraction received through the LCT also corresponds with the amount of workload the steering wheel- and remote control respectively, the common and advanced exercises places on a driver. It would also be interesting to see what more advanced tracks and driving situations would do to the results in the LCT. This research is needed to find out whether or not the LCT is a valid method of measuring driver distraction and what possible changes that needs to be done to improve this method.

8.2 Conclusion

This thesis describes a study of the Volvo P1 navigation system where the safety and usability of the system is evaluated and tested. The results show that there are no significant differences in distraction between either the steering wheel control and the remote control or the common and advanced exercises. The results also show that the usability of the P1 system needs improvement and the design suggestions given in this thesis should be implemented and further analyzed to see if new problems arise and even more changes are needed.
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Appendix

Appendix A: Lane Change Test (LCT) – Instructions

Testledarens instruktioner
Välkommen och tack för att du ställer upp i min studie om navigationssystem och olika reglage för att hantera systemet. Det jag kommer att mäta är hur mycket de olika reglagen distraherar dig som förare och detta gör jag med hjälp av en simulerad köruppgift. Sammanlagt i testet kommer du att köra sju omgångar, vissa med uppgifter och vissa utan för att jag ska kunna jämföra och räkna ut till vilken grad uppgiften distraherar dig som förare. Din medverkan är helt frivillig och du kan när som helst avbryta undersökningsen. Dina data kommer endast att användas i mitt examensarbete, behandlas konfidentiellt och inga personliga uppgifter kommer att lagras eller spridas vidare.

- Visa försökspersonen (FP) interiören med ratt (testpersonen får gärna använda bilens gaspedal men i helbiltestet används endast ratten) och se till att han/hon sitter bekvämt och når alla reglage som behövs i studien.
- Provkör banan några gånger till dess att FP känner sig säker på hur ratten och pedalen fungerar.
- Starta upp navigationssystemet och visa de olika reglagen (fjärrkontrollen och rattreglaget). Beskriv reglagens funktioner.
- Låt FP utföra testuppgifterna ”stillastående” med vart och ett av reglagen. Beskriv steg för steg hur FP ska göra för att utföra de olika handlingarna. Fråga sedan om FP har förstått hur reglagen fungerar och hur uppgifterna ska utföras.

Sägs innan/under provkörningen

Lägg ner lika mycket ansträngning på körningen som på de uppgifter du får och utför uppgiften i normalt tempo, dvs. varken stressat eller överdrivet långsamt. Undvik att köra av vägen. Har du några frågor innan vi börjar?

Uppgifter för försöksledaren
- Se till att banorna körs i en slumpmässig ordning
- Se till att de olika FP använder de olika reglagen i olika ordning så att ej träningseffekt inverkar.
- Efter att FP gjort klart en bana, spara om den med ett namn som du lätt kan sortera efter senare, (ex FP1-enkel)
- Se till att kalibrera ratten mellan varje FP.
- Kontrollera att navigationssystemet är grundinställt mellan varje FP och att lagrade gatunamn med mera raderats.
• Samtidigt som du säger åt FP att börja sin uppgift, ex. ”Ställ in resmål”, trycker du på M på tangentbordet för att börja spela in data. När uppgiften är avklarad (dvs. när FP åter har båda händerna på ratten och ej rör reglagen) trycker du på N för att avsluta inspelningen.

Avslutning
Tacka försökspersonen för dennes medverkan och se till att alla uppgifter genomförts.
Appendix B: Advanced & Common Exercises

Uppgift 1: Common-uppgifter

1. Ställ in resmål
   - Tryck ”Back”
   - Välj ”Ställ in resmål”
   - Välj ”Adress”
   - Stad: Göteborg, Gata: Pianogatan, Gatunummer: 56
   - Starta vägledning

2. Lägg till inrättning
   - Tryck ”Enter”
   - Välj symbolen med en kniv och gaffel
   - Välj ”Runt bilen”
   - Välj ”Alla typer”
   - Välj Bensinstation
   - Välj valfri Shellstation
   - Välj ”Lägg till i resplanen”
   - Välj ”Starta vägledning”

3. Välj skala på karta
   - Tryck ”Enter”
   - Välj symbolen med ett förstoringsglas
   - Välj skalan 500 meter

4. Ändra mellan en och två kartor
   - Tryck ”Enter”
   - Välj symbolen med en jordglob
   - Välj två kartor

5. Sätt resmål på karta
   - Scrolla på kartan med hjälp av styrreglaget
   - Markera en godtycklig plats på kartan och tryck ”Enter”
   - Välj ”Sätt som resmål”
   - Välj ”Starta vägledning”

6. Ställ in delmål
   - Tryck ”Back”
   - Välj ”Resplan”
   - Välj ”Lägg till i resplanen”
   - Välj ”Adress”
• Stad: Göteborg, Gata: Delfingatan, Gatunummer: 2
• Starta vägledning

**Uppgift 2: Advanced-uppgifter**

1. Ändra vägledningsvolym
   - Tryck ”Back”
   - Välj ”Inställningar”
   - Välj ”Systemalternativ”
   - Ändra vägledningsvolymen
   - Återgå till kartläge

2. Undvik motorvägar
   - Tryck ”Back”
   - Välj ”Inställningar”
   - Välj ”Vägvalsinställningar”
   - Välj att undvika motorvägar
   - Återgå till kartläge

3. Läs trafikmeddelande
   - Tryck ”Enter”
   - Välj symbolen med en triangel innehållandes bokstaven i
   - Välj ”Läs meddelande”

4. Lagra valt resmål
   - Tryck ”Back”
   - Välj ”Resplan”
   - Markera ett resmål
   - Välj ”Lagra”
   - Radera det existerande gatunamnet genom att trycka ”Back”
   - Skriv in ordet Hem, varje bokstav bekräftas med ”Enter”
   - Välj ”Lagra”
   - Välj ”Starta vägledning”
**Appendix C: Questionnaire**

**Kompleterande enkät till LCT-test**


<table>
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<th>10</th>
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<tr>
<td>Väldigt däligt/svårt</td>
<td>Daligt/ Något sämre än godtagbart</td>
<td>Godtagbart</td>
<td>Bra/ Bättre än godtagbart</td>
<td>Väldigt bra/enkelt</td>
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**Feedback**

Hur upplevde du att navigationsystemets feedback på dina kommandon fungerade?

**Restriktioner**

Vad tycker du om en idé att begränsa vilka funktioner som ska kunna användas under köring?

**Konsekvens**

Hur konsekvent kändes systemet i fråga om reglagens funktioner? (Fungerade reglaget på liknande sätt var i systemet du än befann dig)

**Läring av kontroller**

Hur enkelt upplevde du att det var att lära sig de olika kontrollerna?

**Taktisk kodning**

Hur fungerar den taktiska kodningen? (Är storlek, form, inbuktningsart, utbuktningsart m.m bra?)

**Kvalitet**

Hur är kvalitetskänslan hos reglagen?

**Läring av systemet**

Hur komplicerat upplevde du att det var att lära sig systemets grunder?

**Effektivitet**

Hur effektivt upplevde du att det var att utföra uppgifterna i systemet?

**Säkerhet**

Hur kändes systemet säkerhetsmässigt? Hur kändes det att utföra uppgifterna ur trafiksäkerhetspunkt?

**Menystruktur**

Hur upplevde du att det var att hitta rätt i menyssystemet?
Navigating Navigation – A Safety and Usability Evaluation of the Volvo P1 Navigation System
Navigating Navigation – En Säkerhets- och Användbarhetsutvärdering av Volvos Navigationssystem P1

Author(s)
Anders Lindgren

Abstract
Navigation systems are today options provided by car manufacturers’ world wide and market predictions suggest that 25 percent of all cars produced by 2009 will have navigation systems installed. However, there are many human-interface issues concerning the use of these navigation systems. This thesis describes a study which evaluates and tests the safety and usability of the Volvo P1 navigation system and also contains suggestions on how the system and its controls should be designed to be safer and easier to use. This is done through heuristic evaluations and a Lane Change Test (LCT). The LCT is used to compare the level of driver distraction between the steering wheel control and remote control and also between common and advanced exercises in the system. Results from the study shows that there are no significant differences in distraction between using the steering wheel control or the remote control. The results also show that there are no significant differences in distraction between the common and advanced exercises. The results of the study are presented as a collection of design proposals that can be used to improve the system’s safety and usability.

Keywords
Navigation Systems, Usability, Safety, Driver Distraction, Lane Change Test