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Designing in-vehicle gestural interfaces

- Minimising visual distraction

Master of Science Thesis

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Cover:
The prototyped gesture system, placed inside a vehicle.
Photo by: David Andersson

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ABSTRACT

The vehicle industry of today is always striving to introduce new innovations and new concepts are being presented by the week. The eager to always be the leading manufacturer within technology and infotainment may sometimes affect safety. This master thesis aimed to utilise gestural interfaces in order to minimise visual distraction when using in-vehicle infotainment systems. This is especially important due to touchscreens’ lack of tactility.

The design process of the thesis has had a human-centered approach and involved potential users in each iteration, to assure that the users’ conception and mental model was taken in consideration when design concepts were developed. During the project, a questionnaire regarding fast access to controls in a vehicle was used as a foundation.

The process included a number of iterations to find an intuitive mapping between gestures and features in a vehicle and resulted in two concepts, which both were evaluated further. One of the two concepts was later considered the more promising one to continue development and testing with and was named GABI (Gesture Action Based Infotainment). The concept incorporated an underlying pattern to achieve inner logic and coherency, and thus simplify for users to learn and remember.

The GABI prototype was lastly evaluated in a driving context, measuring learnability and experienced workload. Findings from the driving test indicated that the participants were able to learn the system with reasonably few iterations and were generally positive towards using the system.

Conclusions from this thesis were that designs using gestures should conform to conventions whenever it is possible to do so. By providing an inner logic, users will learn the system faster and facilitate to make sense of the complex.

Having done initial acceptance tests for GABI, more tests are necessary, to measure and compare the distraction and ensure safe interaction for the driver.

Keywords: gestures, interface, visual distraction, infotainment, HCD, interaction, HMI, touchscreen, vehicle

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Göteborg, July 2013
David Andersson and Frida Wikander

Table of contents

ABBREVIATIONS

AAM	-	Alliance of Automotive Manufacturers
EC	-	Commission of the European Communities
GABI	-	Gesture Action Based Infotainment
HCD	-	Human-Centered Design
HCI	-	Human Computer Interaction
HMI	-	Human-Machine Interface
JAMA	-	Japan Automobile Manufacturers Association
NASA-TLX	-	NASA Task Load Index
NHTSA	-	National Highway Traffic Security Agency
NUI	-	Natural User Interfaces
SGD	-	Single Glance Duration
TGT	-	Total Glance Time
WP	-	Windows Phone

1 INTRODUCTION

The vehicle industry is always searching for what will be the next trend in vehicles. Much research and development related to user experience is related to how the vehicle sounds, smells, how it feels to drive etc. Nowadays the industry seems to focus on how our digital lives can be integrated into our vehicles and what features the vehicle can provide within infotainment. New concepts and systems are introduced in new vehicle models and with each model the systems get more complex and touch interfaces are getting more common. Examples of these concepts include Ericsson's Connected Vehicle Cloud used by Volvo (Ericsson, 2012), Mercedes COMAND system (Mercedes-Benz, n.d.) and the Audi connect services (Audi Connect, n.d.).

The industry works in a technology push manner and each manufacturer is striving to win the race of using the latest and greatest technology. Many of the new produced vehicles available on the market having integrated touchscreens in the center stack used for the infotainment system. Even though this technology push can be intriguing, one also has to be aware of the drawbacks and consequences when integrating new technology into vehicles. A major concern is that there are no real guidelines for how the infotainment interface should look and be interacted with. How should the driver navigate in the system, how can the system give ideal feedback and acknowledge the users' interactions and what level of complexity should a task be allowed?

However, there is no single solution for how to solve this, but there are for example recommendations for the maximum time the users can glance away from the road without drastically increase the risk of an accident (NHTSA, 2012). However, at the same time as embracing new technology, it is necessary to also consider how and why it can improve the efficiency and user experience. The interface has to be consistent for the user to feel comfortable and be able to intuitively control it, no matter if the user has experience of using the application before or not.

1.1 Focus of thesis

This master thesis, which was carried out in cooperation with Semcon Caran AB, investigated the potential of touch interactions in vehicles. Based on existing research concerning touch interfaces in vehicles and research about gestural interfaces, guidelines for how touch interfaces could be integrated in vehicles were developed. These guidelines aimed to minimise visual distraction. The limitations were set to investigate interactions while driving. These guidelines were to be adapted to relevant legal restrictions and existing guidelines and intended to function as guidelines when developing touch interfaces in vehicles. The main focus of the thesis was how to minimise visual distraction while interacting with an in-vehicle infotainment system. This included for example interacting with the native interface of the system. Examples of such interactions could be: browsing, how to open, exit, and switch between applications. The thesis mainly focused on touch interactions, but also briefly discussed free-form and touch gestures.

A concept HMI (Human-Machine Interface), with emphasis on simple gestures that were intuitive, was developed. To evaluate the developed concept the project also included implementing a high fidelity prototype on an iPad.

1.1.1 Research Questions

This master thesis focused on how to utilise gestures aiming for minimising in-vehicle visual distraction. These were the research questions which this master thesis concerned:

> *"How can gestural interfaces be utilised to minimise in-vehicle visual distraction?"*

> *"What signifies a well designed set of gestures?"*

The expected deliveries to Semcon were to compile existing research within the area and develop guidelines for touch interfaces in vehicles while driving. Semcon also wanted a prototype, on an iPad, where these guidelines were applied and results from user tests.

1.2 Delimitations

Since the master thesis was carried out in Sweden, only Swedish legal restrictions were considered. However, global guidelines, from many different countries and organisations were relevant to investigate.

The scope of this master thesis focused on interactions while driving and did not concern physical aspects, such as placement, materials or screen sizes. Furthermore the scope was to investigate the prototype in landscape mode, and not in portrait mode. The project was also delimited to not involve graphics or look and feel. Hence, little resources were devoted to designing graphics and icons for the prototypes. Due to the project's re-focus (see chapter 4.2), changing from a general approach to mainly focus on gestures, much of what previously was included within the thesis had to be excluded. Both feedback and gesture hinting, as well as how to incorporate third-party developers, were excluded from the main scope. Also, due to the time restrictions and the novelty in the area, only initial user studies were conducted in this master thesis.

1.3 Stakeholders

When designing we had several stakeholders in mind. First of all there were vehicle manufacturers. Guidelines play an important role when creating consistent interfaces for vehicles. In addition to this, a set of guidelines enables for, and controls, third-party developers, making their interfaces more suitable for use while driving. This in order to ensure safe driving conditions when using touch interfaces.

There were also companies which were considered stakeholders, developing HMIs intended for the vehicle industry. Semcon, in this case, wanted general guidelines that are not targeted to any specific brand of vehicles, but general enough to be applicable on most brands. Having these guidelines would enable them to lead vehicle manufacturers in the right direction when it comes to touch interactions in vehicles. End users played an important role here since they were the ones to be using the interfaces that were going to be developed based on these previously mentioned guidelines. Bearing this in mind the guidelines had to be produced having the users' needs as a main priority.

Finally, the last stakeholders were we as students, who carried out this project. We were interested in user experiences and making usable interfaces and saw this as an opportunity to influence what future vehicle interactions might be like.

1.4 About Semcon

This master thesis was carried out in cooperation with Semcon at their office at Lindholmen, Gothenburg, Sweden. Semcon is a global consultancy company active in more than 45 countries with around 3000 employees. They are active in many industries and develop both products and services with competence in mechatronics, design, methodology, simulations, electronics, integrated systems etc. As Semcon themselves suggest, they are experts at describing technology in a user friendly way which makes their products easy to use. (Semcon, 2013a)

The head office at Lindholmen in Gothenburg is largely focused towards the automotive industry. Ergonomics/Human-machine interaction is one of Semcon's specialist areas and they have experience working with many well known brands, such as Volvo Cars Corporation, Volvo Trucks and Atlas Copco (Semcon, 2013b).

2 THEORY

This chapter presents the relevant theory for this master thesis. Since it is a master thesis within Interaction Design, designing gestural interfaces, it includes the topics interaction design, human-centred design (HCD), gestural interfaces and an overview of gestures used in smart devices. The thesis is also within the area of driver distraction, which is introduced in this chapter. Relevant for this master thesis are also the guidelines already existing. The most relevant guidelines when designing for in-vehicle displays are also presented in this chapter.

2.1 Interaction design

Every day we interact with numerous products. Turning off the alarm clock in the morning, pulling up the blinds, brushing our teeth, cooking food, watching television or playing games. Albeit mankind has lifelong experience of interacting and designing artefacts people are interacting with, we still have to use products where usability was not prioritised when designing them. How many times have one not struggled with the copy machine, cursing over how it works, or does not work. The general problem products that offer bad user experience have in common is that the design has not been made with the users' perspective in mind, but with a list of requirements that need to be fulfilled.

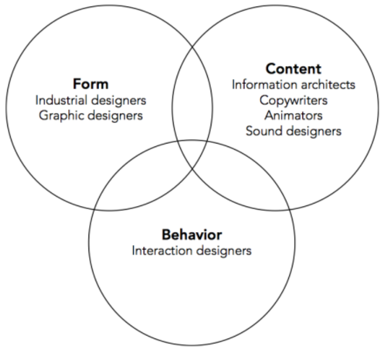

Figure 1 The three concerns which affects user experience (Cooper et. al, 2007).

Interaction design (often abbreviated as IxD) aims to change this approach and bring the user into the picture when designing, resulting in better usability and thus better user experience.

The term interaction design was coined in the mid-1980s by Moggridge and Verplank, two industrial designers who worked on the first laptop, the GRiD Compass. However, the term would not be used in mainstream for another 10 years. (Cooper et. al, 2007)

Cooper et. al. (2007) describes interaction design as the design of behaviour, form, and content. Hence, user experience (UX) of digital products is affected by these three overlapping concerns: form, behaviour, and content, see Figure 1. Hence interaction design does not solely concern behaviour, but also how it relates to form and content.

2.2 Gestural Interfaces

Gestures are used in our everyday life and we perform them both consciously and unconsciously as a way to enhance our language or to give someone a sign. Looking up the word *gesture* in the Merriam-Webster encyclopedia will give you the following definition:

> *"…a movement usually of the body or limbs that expresses or emphasizes an idea, sentiment, or attitude"* *(Merriam-webster, 2012)*

To make a distinction, gestures and gestural interfaces can be divided into two sections: touch and free-form gestures. Touch gestures and touch user interfaces (TUIs) require the user to be in direct contact with a screen or touchpad to interact and control the system. A free-form gesture on the other hand can be performed freely in mid air. Free-form gestural interfaces sometimes use a controller or glove as an input device. However, with new technologies, such as the Microsoft Kinect[1] and Leap Motion[2] it is getting more common to simply use the body as the only input device. (Saffer, 2008) Keep in mind that this thesis focuses mostly on touch gestures with the specific context of controlling it while driving. Gestural interfaces, or interactive gestures, are sometimes also called Natural User Interfaces (NUIs).

In 1983, Shneiderman (1983) described the sensational feeling of a well designed touchscreen interface as direct manipulation. Saffer (2008) agrees and suggests that:

> *"Touch screens and gestural interfaces take direct manipulation to another level... This is the ultimate in direct manipulation: using the body to control the digital (and sometimes even the physical) space around us."* *(Saffer, 2008, p. 4)*

Saffer (2008) also mention that gestural interfaces are not something new:

> *"... everything we do with digital devices requires some sort of physical action to create a digital response. You press a key, and a letter or number appears on-screen. You move a mouse, and a pointer scurries across the screen". (Saffer, 2008, p. 6)*

However, what is new is the way gestural interfaces incorporates the body and how it allows for a much larger variety of gestures. These gestures can be used for selection, navigation, or giving input, but also can be used in completely new ways and control other behaviours and aspects of a system. Even though we might not think of it, many of the products used in everyday life are controlled using our bodies. Examples of this are the motion-activated sink or motion sensors used to turn on and off the lights in a room.

When designing something intended to be used by humans, one should always start by considering who the users are and in what context the product or system will be used. What restrictions does the environment bring and will the users be able to perform what is demanded? Gross movements as well as small, subtle gestures are in general more demanding to perform. The greatest drawback of today's gesture technology is that it in most cases does not provide any physical, haptic, feedback. Instead gestural interfaces often rely on visual- and auditory feedback, which in certain contexts is not preferable.

> *"However natural, interesting, amusing, or innovative and interactive gesture is, if the users' needs aren't met, the design is a failure" (Saffer, 2008, p. 43).*

To be able to design the best possible user experience, it is important to be aware of both the advantages and disadvantages of using gestural interfaces. Perhaps one of the greatest advantages with gestural interfaces is how they are able mimic natural interactions, interactions that we already know and are used to, and allow direct manipulation of objects.

[1] http://www.microsoft.com/en-us/kinectforwindows/
[2] https://www.leapmotion.com/product

Without the need for input devices other than the body, gestural interfaces are much more dynamic than traditional physical interfaces, and can change according to the developers' or the users' own preferences. A good example of this is how virtual keyboards easily can change both layout and language. Figure 2 show the keyboard in an iPhone and how, if the user has selected several favourite keyboards, it is possible to switch between these by holding down the key with a globe on.

Figure 2 iPhone keyboard change

People also seem to be intrigued by gestural interfaces, and may thus be more willing to accept solutions that might not always be the most efficient, but instead most fun. However, in a driving context one must always remember that the primary task is driving the vehicle, and should thus design interactions accordingly.

An in-vehicle infotainment system is an example of a context where it is not recommended to rely on visual feedback. Even though people are getting more comfortable using touchscreens, there is still a fact that most people are much faster writers with a traditional keyboard (Varcholik et al, 2011). With this in mind one should avoid input of heavy data, especially in a driving context were all distractions potentially could be dangerous.

When designing an interface and its interactions one should strive for it to be intuitive and user friendly. However, we would also suggest that with the era of smartphones and touchpads it has become increasingly important with the desirability of a product. Not only should it work as intended, but the aesthetics must also be appealing to the users and be fun to use. As Norman (2002) suggests, humans are more forgiving of mistakes in beautiful things. Also, to stand out among hundreds of thousands of applications, the aesthetics and visual appeal of an application may be what attracts users in first place. Albeit these advantages with an appealing visual interface, when designing for a driving context, the interface and the interactions should make use of a clean design language, without redundant effects and animations, which incorporates simple gestures using as few fingers as possible. Below is a selection of characteristics that Saffer (2008) suggests signifies a good gestural interface.

Discoverable

When designing interactive interfaces one key attribute has always been affordance. Affordance describes how something, a component or a whole interface, appears to the user and its indications for how one should interact with it. Affordance is mostly affected by appearance and texture. Does the button tell the users that it is click-/tappable? (Norman, 2002)

Following up on Norman's (2002) thoughts, Cooper (2007) refers to objects and areas on a screen and whether they mediate the ability to interact with them, that they are *pliant*. Cooper argue that a design must communicate to the users that the components are pliant. There is but one exception to this, which is when designing rich, complex functionality, solely to expert users. Cooper (2007) also lists three ways to communicate pliancy:

- Object hinting
- Cursor hinting
- Selection

Even though the notion of affordance has been known for a long time and most well designed interfaces also have good affordances, the trend for many new designs is headed in the opposite direction with *flat design* (Designmodo, 2013). One example of this is Windows new design language, Modern UI (Msdn.microsoft.com, 2013) which can be seen in Figure 3. Microsoft uses slogans such as "*more with less*" and *"content over chrome"* to spread their message. They also suggest that graphical effects, like gradients and shadows, are excise that should not be used, but instead removed to keep the content in focus and improve readability.

Figure 3 Modern UI on Windows Phone

Trustworthy

To invite users to interaction the systems' overall style must have a feeling corresponding to its context of use. As Saffer (2008) suggest:

> *"the interface needs to look as though it isn't going to steal their money, misuse their personal data, or break down."*. *(Saffer, 2008, p.20)*

However, the first impression is just that, the first impression. When in use, the system must be efficient and perform as expected. The users must feel that they can trust the system and it will work. In analogy with cars, we trust that a car is going to slow down when hitting the brakes and do so based on previous experience from driving and not by the looks of the brake pedal. However, this trust is based on previously being able to brake successfully and as soon as the outcome is not what was expected, the trust is lost, or at least decreased.

Responsive

Since one of the greatest advantages of using a gestural interface is the feeling of being able to directly manipulate an object, it is critical for the system to be fast and responsive in order not to break this experience. A simple rule is that each interaction with the system should be acknowledged one way or another. For the user to experience an action as instantaneous, it should not take longer than 100 ms for the system to provide user feedback. (Saffer, 2008)

Appropriate

Before choosing a certain gesture, think about its meaning in different cultures. However, this would mostly be problematic using free form-gesture. An example of a gesture that can be misinterpreted is the okay sign, holding your forefinger and thumb together in a circular shape. Doing so in Greece or Turkey, you are telling someone that they are homosexual. (Armstrong & Wagner, 2003)

Clever

A good product can predict the needs of its users and adapt in advance in order to achieve the best experience possible. One way to do so is by using adaptive targets, meaning that the system itself predicts next target and makes it easier to interact with. The iPhone keyboard is a good example of how such a system could work. If a user is typing the letters 't' and 'h' in a row, using an English keyboard language, the system will predict that the next letter likely will be 'e' (forming the word "the") and will thus make the touch area of this letter larger than the surrounding letters 'r', 'd', 's' or 'w', however, this adaption is not visually noticeable. (Saffer, 2008) Another example is how the system automatically makes the first letter after punctuation a capital letter.

Playful

> *"Let me explore without getting lost or getting into trouble." (Tidwell, 2006, p. 9)*

A playful interface will encourage the users to explore it, enabling them to learn the system faster. However one must always provide a way for the user to undo and it should be hard to make mistakes. If there is not an obvious way to undo an action, chances are that the user will feel trapped or lost and the exploration stops. Tidwell (2006) describes this as *Safe exploration.*

2.2.1 Attributes of gestures

When designing gestural interfaces and gestures, there are a number of attributes to consider and how each of them contributes to the overall performance and user experience. Below is a list of attributes to consider while designing: (Saffer, 2008).

Presence

To interact with an object, something or someone must be present. For a touchscreen, the presence of a fingertip creates a touch event.

Duration

All gestures have duration and can be done quickly or slowly. In the simplest systems duration might not be of most importance. However, in a driving context, a gesture should be possible to perform quickly, which would minimise the off-road distraction.

Position

Where can the gestures be made? Are there specific zones dedicated for interaction or can the gestures be recognised everywhere?

Motion

Does the user have to move and is a certain velocity demanded? For some system the mere existence of any motion is enough, like motion sensors used to control lighting.

Pressure

There are different types of devices and touchscreens that work differently. Using an iPad it does not matter how hard a touch is, while devices such as drawing boards from Wacom[3] are pressure sensitive and allows drawing both thin and thick lines simply by changing pressure.

Size

Gestures can range from very subtle to gross movements and may thus decide whether it is necessary to employ an additional input device or not.

Orientation

Are the users facing the system while interacting with it? The orientation is in particular contexts, such as games and environment, very important.

Including objects

Gestural interfaces may allow the users to employ physical objects while interacting. Simple systems will treat the object as an extension of the human body. More sophisticated systems however, can recognise objects and allow the users to employ them in context.

Number of touch points/combinations

Many of the modern products and gestural interfaces support interactions with several fingers, objects, or people simultaneously. This can be used to allow for combinations of gestures that together trigger actions. An example of a commonly used multi-touch gesture is two-finger pinch, used to zoom in or out.

Sequence

Gestures does not always have to be performed in isolation, but can also sometimes be done in a sequence to trigger an action different to the gestures done separately.

Number of participants

With more sophisticated technology and devices such as the Microsoft Surface[4] or Microsoft Kinect[5], which both allow multiple persons to interact simultaneously, it can sometimes be worthwhile to consider if and how a product can be designed for this.

In a driving context, critical attributes might for example be duration, motion, number of touch points, and position, since each time the drivers are distracted from the road, the risk for an accident increases. Thus has the gesture to be easy to perform, so that the driver can maintain the attention on the main task, driving. It is also important to use quick gestures that do not require the drivers to let go of the steering wheel for too long. If the gestures are required to be performed in a specific zone, again, the drivers must look at the system to see where to aim and thus lose attention from the road. Lastly, if the gestures are physically demanding it will likely result in the driver avoiding it, and the gestures might affect driving performance.

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[3] http://www.wacom.com/products/pen-tablets
[4] http://www.microsoft.com/surface/
[5] http://www.microsoft.com/en-us/kinectforwindows/

2.2.2 Choosing gestures

When choosing a gesture for a specific action it is important to think of when and how the action will be used. An action that will be performed often should have a gesture that is quick and easy to perform.

> *"The best interactive gestures are those that take the complex and make them simple and elegant."*(Saffer, 2008, p. 28)

It is also important to allow both beginners and advanced users to feel comfortable and feel that they are using the system efficiently. Similar to how many traditional interfaces allow users to evolve from beginners to experienced users, by using both menus and keyboard shortcuts, gestural interfaces should provide both simple gestures used by beginners, as well as more sophisticated or complex gestures, for more advanced users, which could be used as shortcuts to trigger complete sets of actions. Despite all opportunities of using gestures, one simple rule to keep in mind is that the more complicated the gesture, the fewer the people will be able to perform it. (Saffer, 2008; Cooper et. al., 2007)

Even though one might think that a certain gesture is universally true, chances are that people have different perceptions, depending on previous experience. To determine what gestures people find most intuitive, the best approach is often to simply ask the intended user group about their preferences. Asking several users might show a pattern for how they think. One can approach this either by presenting predetermined gestures or solutions and simply ask the users which they prefer, or approach it the other way around and ask the users what gesture would control a specific feature. Another alternative is to present the users with a gesture and ask what feature they expect the gestures to trigger. (Saffer, 2008)

Saffer (2008) lists a few ergonomic principles to consider when designing gestures and their motion.

- Avoid "outer positions", those that cause hyperextension or extreme stretches
- Avoid repetition
- Relax muscles
- Utilize relaxed neutral positions
- Avoid staying in a static position
- Avoid internal and external force on joints

These principles could be applicable not only to an arm, but a hand, a finger, or the whole body. Exhausting and wearing positions should always be avoided if possible.

2.2.3 Metaphors and idioms in gestures

Metaphors in user interfaces and interactions mean how a gesture, for a purpose or attribute, mimics our natural movements and behaviour. An example can be when volume is increased by a gesture of raising the hand up, and decreased by lowering it. Metaphors are understood intuitively hence they can be used without the user having to learn the meaning of the metaphor. (Cooper et. al., 2002)

Idioms on the other hand are connections between gestures to a purpose or attribute which have to be learned. An example could when an application uses the gesture to swipe to the right to delete an item, this does not have a natural mapping and thus has to be learned. Idioms also exists to a great extent in our languages where for example a gadget can be described as both hot and cold, both in the meaning of desirability, this is not intuitive but it is something which is learned. (Cooper et. al., 2002)

Even though metaphors are more effective, concerning learning and remembering, they have some major drawbacks. One example is that they have to be perceived the same by both the user and the designer to work, another is that it often scales poorly. Many of the objects in our interfaces are idiomatic and this is not a problem since the human is good at remembering idioms. The learning of an idiom should not be hard, and a good idiom needs only to be learned once. (Cooper et. al., 2002)

2.3 Gestures in smart devices

There are currently three large operative systems running on most of the smart devices which people use. They are Android, Apple´s iOS and Windows Phone (WP) and they all have framed guidelines on how to develop applications for their specific platforms (Developer.android.com, n.d.; Developer.apple.com, n.d.; Msdn.microsoft.com, 2013). Included in these guidelines are explanations of gestures which the systems support. The importance of the gestures being consistent throughout all the applications is also highlighted (Developer.apple.com, n.d.). The users learn different gestures and doing some gesture, they expect it to work the same in other applications and platforms as well.

Even though they are different systems, the interactions used on the devices are often similar. Table 1 shows a summary of the core gestures in the different operative systems and how they are performed.

Gesture	Action	Interaction	Available in
Tap/touch	Select or press a control	Singe quick touch on the screen.	Android, iOS, WP
Double tap	Zoom in on content or application	Two quick touches on the screen	Android, iOS, WP
Pinch/stretch or pinch close/open	Zoom in (Stretch/Pinch open) or out (Pinch/Pinch close) with direct manipulation	Use two fingers to touch and move them towards each other or spread them apart.	Android, iOS, WP
Pan/drag	Move or reorder content with direct manipulation	On Android it is performed by starting with a long press followed by moving the finger in any direction On iOS and WP it is performed with a touch followed by moving the finger in any direction	Android, iOS, WP
Touch and hold/long press	On Android it is used to enter the data selection mode On iOS it is used to get a magnified view of the selected text On WP it is used to display a context menu or options page	Touch the screen and let the finger remain still for a while to then release	Android, iOS, WP
Swipe	On Android it is used to scroll or navigate between views On iOS in is used to reveal the delete button	Touch the screen using a sweeping motion	Android, iOS
Flick	On iOS it is used to scroll or pan quickly On WP it is used to move whole canvas	Start by touch and move the finger rapidly finalise the gesture by lift the finger off the screen	iOS, WP
Shake	Used to undo or redo an action	Shake the device sharply	iOS

Table 1 Summary of available gestures in Android, iOS and WP.

As can be seen, some of the gesture-interaction-action couplings are shared between all the platforms, namely: tap/touch, double tap, pinch/stretch or pinch close/open. There is also a category of gestures where the interaction is alike but the action differs. There are two gestures which belong to this category: touch and hold/long press and swipe. What can be noted from the comparison is that the touch and hold/long press gesture, which the Android guidelines advises the developers not to use for contextual menus, is exactly what WP uses it for.

The opposite of the previously mentioned category is when the action is alike but the interaction differs. The pan/drag gesture belongs to this category. One could argue that even though the drag gesture in Android has a different interaction in the guidelines, it is still possible to do a drag the way iOS and WP do it, but it is not defined as a core gesture in the Android platform.

Of course there are applications that make exceptions to the defined core gestures and a gesture which is not defined for a platform might be implemented to function the same way as the other platforms or in an application-specific way.

The conclusion of the gesture summary is that many of the gestures used on the smartphones are similar. However, there are cross platform inconsistencies, which can be confusing for the users since the devices are not behaving equally when performing the same gesture on the different platforms. This makes it hard to design new systems, since users have different opinions of what the gestures do.

Using gestures enables interaction without visual distraction, which is an important factor in the next topic of driver distraction.

2.4 Driver Distraction

Driver distraction is an extensive area and to read all research conducted is not possible within the time frame given for this master thesis. However, it is an important topic, both for the thesis and in general. Hence, what follows in this chapter is a brief overview of the research and regulations within the topic of driver distraction.

There is no agreed definition of driver distraction. However, National Highway Traffic Safety Administration (NHTSA) describes it as the

> *"...inattention that occurs when drivers divert their attention away from the driving task to focus on another activity".* *(NHTSA, 2012 p. 5)*

Studies have estimated secondary task inattention to contributed to over 22 percent of all near-crash and crashes (Klauer et al., 2006), estimated on data from the 100-Car Naturalistic Driving Study done the US by Neale et al. (2002). These tasks can be divided into three categories, adapted from NHTSA (2012):

Visual

When the drivers are required to look away from the road in order to get visual information.

Cognitive

When the drivers are required to direct their mental resources away from the primary driving task.

Physical

When the drivers are required to use the body to physically manipulate an object.

NHTSA (2012) also highlights the importance of frequency and duration of a task, suggesting that even a task considered simple and fast, can still have a big impact on driver distraction. If a task is being performed frequently, it can be of greater risk than a more complicated task seldom performed.

Green (2000) identifies two activities which are critical reasons for causing accidents, namely *eyes-off-the-road* and *mind-off-the-road*. One can clearly understand why taking your eyes off the road is a reason for crashing and why it is of highest concern to encourage the driver to keep their eyes on the road. However, the question about whether or not a cognitive workload is dangerous is more controversial and much research has been conducted in the area (Harbluk and Noy, 2002; Tsimhoni and Green, 2001; Klauer et al., 2006). Mind off the road concerns situations when the driver is cognitively distracted from the primary task of driving the vehicle. This includes listening to auditory messages and talking on the phone, but also daydreaming or thinking of a complex problem.

Further, one can question whether it is possible to simply divide the driver's resources into visual and mental. Wickens (2002) describes the origin of the multiple resource theory and how it accounts for differences in tasks and their interference. He also propose a four space model, aiming to give a deeper understanding of this interference and how, with knowledge, it is possible design around this problem. The model is used to predict and also calculate the interference between two tasks when they are performed simultaneously. The paper concludes that using cross-modal (auditory-visual) time sharing activities is better than using intra-modal (visual-visual/auditory-auditory). This could be used as a guide for designers to decide how for example an interface should be controlled, or give feedback.

When designing interfaces which are meant not to be distracting it is critical to test it with users. There are methods for measuring how driving performance is correlated to distraction. Burns et al. (2010) and Tsimhoni and Green (2001) identify some concepts that are used when evaluating distraction, for example *total time duration to complete task, total glance duration, number of glances*. Some concepts are more test-specific, for example *lane departure* when doing a driver simulation and *total shutter open time* when doing an occlusion-based test method. Burns et al. (2010) also emphasises the importance of the *total time duration to complete task* and concepts which measures duration when evaluating distraction. They also argue that test results of these kinds of evaluations could and should be used as early as possible in the design process to avoid difficult and expensive redesigning at a later stage.

Another concept that can be used is the subjective experienced workload while performing a task, which can be measured with NASA-TLX (Hart & Staveland, 1988).

Naturally, it is important to have knowledge about legal restrictions for what is allowed. Currently, in Sweden, there are no specific laws that prohibit drivers to use handheld devices while driving (Patten et al., 2003). However, in the traffic regulation there is a paragraph stating (freely translated) that in order to avoid traffic accidents the driver should observe the care and caution required by the circumstances (Trafikförordningen 1998:1276 2 ch. 1 §). As the last country in the European Union without any laws requiring hands-free or similar devices when driving, the Swedish traffic committee discuss and propose to prohibit all mobile devices that distract the driver from the main task of driving and thus endangering the road safety (Riksdagsförvaltningen, 2013).

2.5 Existing guidelines

There are mainly three large instances of guidelines concerning the design of in-vehicle information and communication systems. These guidelines originate from National Highway Traffic Safety Administration (NHTSA) (NHTSA, 2012), the European Commission (EC, 2008) and Japan Automotive Manufacturers Association (JAMA) (JAMA, 2004). In addition to this there are also the Alliance's guidelines, which is the Alliance of Automobile Manufacturers' (from now AAM) response to a challenge by NHTSA to address the rising concerns of distraction while driving (AAM, 2006). It is on the Alliance's guidelines, NHTSA have based their guidelines, which also is why both guidelines are being similar in many cases. However what can be noted is that the different instances seem to agree on many things, but some of the guidelines are more detailed than others. What follows is a summary of the core values in the different guidelines.

One of the most important tasks of an in-vehicle information system is to be transparent enough to not yield another distraction object for the driver and to avoid creating potentially hazardous situations (EC, 2008). This has been formulated in different ways by the different guidelines (EC, 2008; JAMA, 2004; AAM, 2006) here is the AAM's formulation:

> *"Systems with visual displays should be designed such that the driver can complete the desired task with sequential glances that are brief enough not to adversely affect driving" (AAM, 2006, p. 38)*

The vehicle information system should also be designed to not distract the driver by using visually entertaining material on the screen (AAM, 2006; EC, 2008; JAMA, 2004) and should always strive towards having as little effect on the driver performance and attention as possible.

Driving is a task requiring much attention from the driver and a secondary task must not draw the attention from the primary driving task. Due to this there are guidelines concerning different time and glance aspects that can be measured while driving. The AAM also states that their guidelines can be revised if research presents new information (AAM, 2006). What follow are four numbers concerning time aspects:

Total glance time (TGT)

The summary of the glance durations to complete a task. The recommendations for the TGT are to be less than:

- 8 seconds (JAMA, 2004)
- 12 seconds (NHTSA, 2012)
- 20 seconds (AAM, 2006)

Single glance duration (SGD)

The time for a specific glance on the screen. The guideline for this is that the maximum SGD should not exceed 2 seconds (NHTSA, 2012; AAM, 2006).

The SGD value originates from the 100-car naturalistic driving study which indicates that of glances over two seconds increases the risk of crash or near-crash events (Bischoff, 2007). The 2-seconds rule is also what this project aims at. To keep all off-road glances less than two seconds.

There are more guidelines which apply to many different areas, like feedback, messages, symbols etc. For further reading, see Appendix II.

3 METHODOLOGY

This chapter presents theory about relevant methods for the project. The methods are placed in chronological order.

3.1 Human-centred design

When designing a product there are specifications and requirements to follow, but often these have not considered the users' needs and goals (Cooper et. al., 2007). This is what the Human-centered design (HCD) approach strive to address by having the users' perspective and incorporating usability methods into the design process and thereby design systems which are usable (Maguire, 2001). The designer needs to have an understanding of the users' goals needs or motivations as well as the business goals in order to be able to create successful designs. To meet these goals the design process should always precede the implementation of a system. (Cooper et. al., 2007)

In general the HCD process can be summarised with four key points of first having users actively involved in the design process and have a clear understanding of user and task requirements. The second point is to allocate functions between user and system properly. The third point concerns the process, which should incorporate iteration of design solutions. Lastly, the design team should be multidisciplinary. (Maguire, 2001)

3.2 Literature study

A literature study is a comprehensive study and interpretation of literature that is related to a particular topic. When undertaking a literature study, one identifies specific questions that should be answered by searching and analysing gathered information. A literature review is a good approach to summarise the knowledge that exists within a topic of interest and could be used to influence a designer's output. The review helps the reader to comprehend the topic and read about the most significant and important parts without being forced to access and read each individual research report. (Aveyard, 2010; Jones, 1992)

3.3 Benchmarking

In order to get the best result as possible, benchmarking is a way of gathering information about what already exist. This includes finding best practices, innovative ideas, effective solutions and of course learning from others' mistakes. Performing benchmarking helps to learn from others' experience and can be of great advantage in own projects. (Bogan & English, 1994)

3.4 Interviews

Interviewing is a common method to use when one wishes to ask the users about opinions and thoughts. Kahn and Cannell (1957) describe interviews as a *"conversation with a purpose"*, and it can be very much like it. There are mainly four types of interviews: unstructured (also known as open-ended), semi-structured, structured, and group interviews (Fontana and Frey, 1994). Unstructured interviews are most similar to an ordinary conversation since these are conducted without the interviewer adhering to a strict manuscript. In a structured interview the interviewer is making sure the discussion follows the predetermined path and the semi-structured interview is, as its name suggests, a compromise between the previous two. A group interview instead involves a small group of people with a single interviewer who have prepared a set of topics to discuss. Which approach is most suitable all depends on the purpose of the interview. (Preece, 2002)

3.5 Questionnaire

A common method for gathering quantitative data about a topic from the users, is to use questionnaires. Questionnaires are well established and suitable to use for collecting large amounts of data and provide a general opinion among a large user group. Questionnaires are in many ways similar to interviews, but with the advantage that it does not demand the interviewee to be situated on a particular place at a specific time. Similar to how interviews use closed or open questions, so can questionnaires. To collect as much useful information as possible one has to be skilled and careful when writing the questions. Each question needs to be asked in a proper and clear way, making sure that it is interpreted the same way by everyone answering it. This to be able to analyse and draw any conclusions from it. (Preece, 2002)

Questionnaires can be used both on their own or complementary to other methods, to clarify or deepen the understanding of the topic. It often starts with general information about the interviewee, such as gender, age, experience, etc. This information is used to find the range of the user group and in many cases to categorise the interviewees. Following the general questions, subject specific questions which contribute to the final goal are asked. To make it easier to answer the questionnaire it can be a good idea to divide it into subsections. This is especially important if the questionnaire is long. (Preece, 2002)

3.6 Think aloud

The think-aloud method consists of a simple concept where the participants are instructed to use an artefact or interface and share their thoughts as they evolve during the test session. (Lewis and Rieman, 1994) Even though the concept is simple there are some things that the test leader has to bear in mind when performing the study. The role of the test leader is the role of an observer and should not influence the participants in any direction but stay as neutral as possible but still encourage the participants to perform the tasks and sharing their thoughts continuously. However, the test leader might have to help the participants if needed. The test leader should use pre-decided criterions for when to provide help, to avoid misleading results. Moreover, potential help should be carefully documented.

This method collects qualitative data and the results reveal what the users think about the artefact being tested. It also not only gives you what the users think, but often also why they think so. (Nielsen, 2012)

3.7 Skewing

Skewing (Lundgren & Gkouskos, 2013) is a method used on an existing artefact to generate new ideas and concepts. It is conducted by analysing the artefact with a given framework, for this thesis we are using Lundgren’s list of interaction-related properties (Lundgren, 2011), and then change attributes or properties to an opposite of what currently is. Doing so may result in odd or completely useless solutions. However, it may also be that something different and useful is developed as a result of this method.

3.8 SCAMPER

Similar to skewing, SCAMPER does also rely on existing artefacts that are being manipulated to generate new ideas and solutions. As Michalko (2006) states:

> *"When your imagination is as blank as a waiter's stare, take an existing item and manipulate it into a new idea. Remember that everything new is just an addition or modification to something that already existed."* *(Michalko, 2006, p.72)*

The ideology of SCAMPER is to approach a problem from every angle to find the best possible solution to increase the chances of finding the best possible solution to a particular problem. Asking a group of people what colour an artefact has will likely result in many different answers. Tell a group of people to move from point A to point B, they will likely travel by different means of transportation depending on previous experiences and the purpose of travelling. Solving an equation can be done in many different ways, presented differently but with the same answer. (Michalko, 2006)

Basically, SCAMPER is a list of questions used to widen the designer's mind and come up with new solutions and follows these main keywords**:**

Substitute something
Combine it with something else
Adapt something to it
Modify or **M**agnify it
Put it to some other use
Eliminate something
Reverse or **R**earrange it

To use SCAMPER first isolate the challenge or subject to evaluate, then ask SCAMPER questions about each step of the challenge or subject and see what new ideas emerge. Asking these questions is like tapping all over the challenge with a hammer to see where the hollow spots are. (Michalko, 2006)

3.9 Workshop

As a part of a data gathering workshops can be used. Here a group of stakeholders are assembled for discussing and collecting multiple viewpoints. Workshops are used to collect mostly qualitative data. The advantages of using workshops are that the stakeholders can reach consensus and it encourages interaction between stakeholders and developers. However, when assembling a group of people there is always the risk of strong personalities taking over, so the choice of participants is important. A workshop, similar to interviews, can be either a structured or informal process. (Preece et. al., 2002)

3.10 Extreme characters

Early in the design process, while tackling a problem from all directions using different methods, extreme characters can be used to create very specific, and extreme, use scenarios. A key feature of the method is to be forced to think in new ways when designing. Using extreme characters lets you design for a specific user, contrary to ordinary design where you usually target a group of users. This design should be extremely subjective to focus on the extreme characteristics of the character, including exaggerated emotions and character traits. Having only one, extreme, user lets the design focus on the specific user's needs and wishes, resulting in a design which is completely tailor made for that user. (Djajadiningrat et al., 2000)

3.11 Stating the objectives

This is a method to identify and evaluate the objectives to find the core of a project. In order to succeed with a project it is a great advantage to have suitable aims and objectives with respect to the resources from the start. However, doing this is itself a learning process and is difficult, especially in novel projects.

Stating the objectives includes three parts, where the first one is to identify the situation. The second part is to find features of the situation which make the project valid from the stakeholders' point of view. These features can include motivations, expectations, resources and essential objectives. Fulfilling these objectives is most important for the validity of the project. The third part is to ensure that during the project objectives and available information are compatible with each other. (Jones, 1992)

3.12 Prototyping

After eliciting the requirements of a product, the design activities start. Design can be divided into two types: conceptual and physical. Conceptual design covers how a product will behave and what it will do, while physical design rather concerns details and looks. The design process should be iterative and involve users in each iteration, until the results are satisfying. (Preece et al., 2002)

To make the evaluation more effective and accurate, prototypes are often used. A prototype may in an early stage simply be made of paper and cardboard and used to evaluate a first impression of the system. A low-fidelity prototype, such as one made of paper, is not used to evaluate the complete functionality or the look and feel of the final product, but as a fast and cheap solution to show a proof-of-concept that can be used to discuss around and elicit the first requirements for the product. (Preece et al., 2002)

Along the design process, the prototypes fidelity develops into something very similar to the final product. A high-fidelity prototype, a fully interactive prototype with complete functionality, is expensive to develop and thus used later in the design process. It is used to evaluate not only the general impression, but all details of the product and mainly used to confirm that it fulfils all the requirements previously elicited. (Preece et. al., 2002)

3.13 Wizard of Oz

Not all functionality is available when using a low-fidelity prototype. A method that can be applicable in such a situation is Wizard of Oz, sometimes also referred to as *man behind the curtain* (Saffer, 2008), a technique where the user is interacting with the prototype as intended and someone manually reacts to the interaction and changes the prototype accordingly.

3.14 Heuristic evaluation

Heuristic evaluation can be thought of as:

> *"…an informal method of usability analysis where a number of evaluators are presented with an interface design and asked to comment on it." (Nielsen and Molich, 1990, p. 249)*

To do a proper evaluation one should follow guidelines about usability. However, most people do not, but rather judge according to their own preferences, intuition, and common sense.

Nielsen and Molich tried to mitigate this problem by developing a simple set of rules to follow (Molich and Nielsen, 1990):

- Simple and natural dialogue
- Speak the user's language
- Minimize user memory load
- Be consistent
- Provide feedback
- Provide clearly marked exits
- Provide shortcuts
- Good error messages
- Prevent errors

Using a more complete set of guidelines to validate an interface would be considered too formal and not fit into the approach of heuristic evaluation. However, it is important to be aware that one could never know if all usability problems are found. One might stumble over something never tested before and thus there is always a possibility of discovering new things.

As concluded by Nielsen and Molich (1990) in their study, heuristic evaluation is difficult and that it is necessary to use multiple persons for this method to be appropriate when trying to elicit errors in an application or interface. There is also the fact that identifying errors not necessarily means that a solution can be provided, thus only taking it half way.

However, there are also advantages of using this method to evaluate and validate an interface, advantages that often overrule the drawbacks. One such advantage is the fact that doing an heuristic evaluation is cheap. One does not need any particular equipment or be at a certain location, as well as it does not require detailed planning in advance. It is also quite easy to motivate other people to participate, since the task does not require extensive description, but is rather intuitive and can be done early in a process.

3.15 Expert evaluation

Similar to heuristic evaluation, expert evaluation is used to evaluate user interfaces and systems. As the name suggests the evaluation is done by one or more experts. These experts have education, professional training or experience to make informed decisions about the usability aspects of the product or system. Having experts evaluating a system enables the evaluation to be more narrow and focus on more specific issues within the interface, compared to heuristic evaluation where the users' can do the evaluation and yields a more general result. (Jordan, 1998)

The advantages with the method are that no users are needed for the evaluation, making it an easy and cheap method. The experts having experience with usability should lead to solutions of the potential usability problems. The disadvantages are that any potential problems, which the experts find, might not be a cause of problem for the users. The result of the method is also completely dependent on the experts' expertise within the area. (Jordan, 1998)

3.16 NASA Task Load Index (NASA-TLX)

Workload is referred to the cost of resources to accomplish a specific task for the user. NASA-TLX is a method to subjectively evaluate the users' workload, originally developed to measure the workload within the areas of aviation, focus and language (Hart, 2006). The workload is divided into six factors: Mental Demand, Physical Demand, Temporal Demand, Performance, Effort and Frustration. These aspects are considered to have an impact of the workload when performing a task or series of tasks. The factors are rated individually but are summed up to get a value of the estimated workload. Before the summary, these factors are prioritised pair wise to get a weight of each factor. This weight represents the contribution the specific factor had on the total workload. The workload is a percentage which can be compared to other workload percentages. (Hart & Staveland, 1988)

4 PROCESS

The process during the thesis had a human-centered design approach and can be divided into five main stages: background, ideation, refinement, evaluation, and conclusion. First stage did concern research and background information within the topic as well as benchmarking systems that currently existed on the market. In accordance with the approach of human-centered design, and to get an understanding of the users' opinions, a survey asking questions about which features people wanted fastest access to, was conducted. In parallel with literature research, much effort was put into generating new ideas and concepts, in an ideation phase, using methods such as SCAMPER and Scewing, as well as sketching solutions to specific features in a vehicle (see Figure 4). We also started to do interviews with people who had been working with in-vehicle HMI as well as application development.

Figure 4 A mock-up of a concept for controlling the fan

While still doing research and concept development, we realised that the scope was too wide and included too much for us to manage within the timeframe of a master thesis. Hence, the thesis needed to be narrowed and focus only on one specific component within infotainment, instead of trying to include everything. Re-focusing the thesis resulted in excluding most parts of the previous scope and instead only do research on gestures and how these could be incorporated in in-vehicle infotainment systems to minimise visual distraction. From there, the project kept an iterative human-centered approach where each iteration used feedback from user tests as a foundation to refine the concepts. As a final step the concepts were evaluated by experts and then tested in a driving context to get a conception of how such a system would perform and the acceptance among potential users.

4.1 Initial process plan

When this thesis started the initial scope given by Semcon was very broad and covered research within not only gestures, but also how to give the users hints about possible gestures and how they should be performed, how to provide feedback to the user, how to allow third-party developers to develop to the platform, and how their guidelines about gestures and aesthetics could be developed. The limitations were set to investigate interactions while driving and the initial research questions were formulated as follows:

> *"How should a touchscreen based infotainment HMI, in an efficient and safe manner, provide the driver with information and feedback while driving? Are there any circumstances in which a gesture recognition system seems preferable to a touch based interface?"*

The outcome of the thesis, our deliveries, were planned to include a compilation of existing research within the area, as well as guidelines for how touch gestures should be designed and combined to create coherency and allow as many users as possible. We also intended to develop a prototype which could be used to show and test the concept. Since we both had previous experience of developing in Objective-C for iOS, the prototype was to be implemented on an iPad. All results from user tests and evaluations were considered deliverables as they would be included in the final thesis report.

To be able to think outside the box and not copy already existing features and solutions, we needed to conduct different idea generating sessions using different methods. The approach was to examine already existing systems and modify these in numerous ways to hopefully generate new, good, concepts that had not previously been done. In parallel with this work we also started a first user test about gestures to find out what gestures people would like to use for controlling specific features in a vehicle. This user test is the initial step to what later turned out as a whole gesture mapping process.

As a last step in our ideation stage, we wanted to widen the scope even more by taking the generation of concepts to the extreme using extreme characters in a workshop. Again, much work would be done without knowing what might come out of it, but still with a chance of generating unique concepts and solutions to continue to refine.

4.2 Re-focus and continuation

Halfway through the project we realised that it was not realistic to deliver a proper result trying to include all parameters, given the time frame for this master thesis. Hence, In consensus with our supervisors at Semcon and Chalmers, a session to *state the objectives* (described in the methodology chapter) was conducted. To be able to complete the project within the limited timeframe, it was important to get a better overview of the thesis and identify critical conditions as well as to decide what features that were most relevant. This resulted in a narrower, and a more suitable, scope with focus on gestures and how these could be designed and mapped to actions or features in a vehicle.

At this point many of the previous idea generating sessions that had been conducted and the result of these, that previously was considered meaningful, could not be used any longer. However, it was not done all for nothing. We learned a lot about conducting user studies which we could apply later in the project, and we got to evaluate existing systems to start thinking about alternative ways of interacting.

Albeit parts of previous work was no longer relevant after re-focusing the project, it resulted in a much clearer goal to what the thesis aimed at, as well as the path to achieve this. The initial user tests about how people related to gestures became the foundation to an iterative process of mapping a given set of actions with gestures. In each iteration, some gestures were considered done, as they seemed intuitive enough and the majority agreed on them, while other gestures were completely excluded. After three main iterations the process ended up with a 1:1 mapping between 12 actions and gestures.

During the gesture mapping process, two theories developed into two different concepts. A first concept, where the user never used more than three fingers, but without a strong foundation that tied the concept together. The second concept utilised an underlying pattern to map the number of fingers used to a category of actions, in this case music, climate, and system specific actions.

The two concepts were used in a last iteration and afterwards also analysed by experts within the topic, with the goal to decide which of the two concepts that was most intuitive and the easiest to use. Finally one last user test was conducted, this time with the ambition to evaluate the concept and prototype in a driving context.

The next parts of the process chapter will discuss the different parts in detail, with short motivations about the choice of methods, as well as the outcome of user tests and evaluations.

4.3 Choice of methods

What follows is a presentation of the methods used during the project with short motivations to why these methods were used.

Human-centered design (HCD)

The strive throughout the process was to utilise HCD as a methodological framework for the thesis, and involve users in every stage throughout the project. To achieve this, most iterations in the process have started with user tests and studies resulting in feedback about what to continue to work with and improve until next iteration. Most of the user studies were preceded by a pilot study where potential flaws in the test could be identified and corrected.

Literature study and Benchmarking

Before throwing ourselves at the challenge, a strong foundation of knowledge was necessary, which meant collecting relevant information about many different areas, such as driver distraction, existing guidelines, gesture theory, and existing systems. This continued throughout the whole project but was mainly concentrated to the beginning of the project.

Naturally, there are already vehicles available on the market that have integrated touchscreens in the center stack. To get a better understanding of how touchscreens were used in infotainment systems of today, a benchmarking session was performed. This was done by visiting automotive retailers around Gothenburg, asking them to demo the systems and let us use them. The focus of the benchmarking was to investigate existing systems and examine interactions and solutions. It was considered better to visit retailers and get a real life experience and actually get to interact with the system. The cars chosen to examine was picked because there was a touchscreen installed, or because it represented the infotainment solution from a specific manufacturer. However, we also considered it interesting to see systems from other manufacturers that we were not able to visit, such as Tesla Model S [6], since they had models that were considered relevant.

SCAMPER / Skewing / Workshop

Early in the process it was necessary to generate ideas for new concepts or solutions, and to do so both SCAMPER and Scewing sessions were conducted. A workshop as a part of the ideation phase was also conducted. Skewing and SCAMPER helped analysing existing

[6] http://www.teslamotors.com/models

systems and the workshop created new ideas for infotainment systems using the method Extreme Characters.

Stating the objectives

This method was used to get an overview of the entire thesis and the different components it consisted of. Stating the objectives helped to find the essence of the project but maintain the validity. By narrowing the scope we would be able to deliver a proper result given the available resources. Before re-focusing the project, one of the priorities was to generate concept ideas. Many of the previous components of the thesis were excluded, which also meant that results from previous work now was irrelevant and left out of the thesis.

Questionnaire

The initial step of the process was to quickly assemble a foundation to further work with. To do so, we conducted a survey to investigate the importance of easy access to controls of features in a vehicle. As Seemann (2012) suggest, quantitative methods often lack of design insight to create inspiring new solutions to problems. On the other hand, insights unveiled using solely qualitative research can be very fragile if not backed up by hard numbers representing potential users or the population. His solution is to integrate the two approaches with each other which

> *"Helps strategists leverage the why as well as the what when making important decisions"* *(Seemann, 2012, p. 58)*

The survey enabled us to reach a much broader range of participants which was considered important for the validity of the results, since much of the project, like what actions to use for the gesture mapping, were based on findings from this survey.

Gesture mapping

To investigate how people would map actions, which were found important during the survey, to gestures, a first iteration of tests was conducted. An informal interview structure (unstructured) was used, where the participants were asked to perform gestures that would control different features or actions. This approach was chosen to gather as diverse suggestions to gestures as possible. During the gesture mapping tests, the participants were encouraged to think aloud while thinking about and performing gestures, in order to understand how they were reasoning when choosing a gesture.

In order to develop concepts from the results, data from the first iteration of gesture mapping had to be refined further. In a second gesture mapping iteration, the participants got to map actions, without an intuitive mapping, based on the result from the previous iteration. Analysing the data from these iterations made it possible to create two concepts. A third iteration tests was conducted to evaluate the concepts and confirm the concepts' mapping.

Prototyping and expert evaluation

Already in an early stage of the gesture mapping it could be noticed that people had a hard time imagining many of the gestures and what they represented, without the right context and feedback. One such example was skipping to next track, which some people wanted to do by swiping from left to right, and some the opposite (swiping from right to left). However, what answer the person gave, highly depended on how he or she was asked to describe the gesture and whether it could be performed on a touchscreen or just on a piece of paper. To tackle this uncertainty and risk of assembling incorrect answers because of the wrong context, the two concepts were early prototyped as high-fidelity prototypes that did not focus on the visual, but on the experience and feeling when interacting with the system. We also talked about using Wizard of Oz for giving feedback when testing these prototypes, but we concluded that it would be hard for us to imitate the fan or the changing temperature in a good way, but would basically instead disrupt the user experience by faking the feedback.

The prototypes were evaluated by other students doing their master thesis within the area of touch interactions and thus considered experts. The experts were used because of their ability to objectively analyse the concepts and draw general conclusions about the user experience. Due to time restrictions, the intention of the expert evaluations was to determine which of the two prototypes was the more promising and test that one in a driving context

Evaluation of final prototype

To finally evaluate the prototype which was selected from the expert evaluation, a driving test was conducted. The driving test was considered useful to get an indication of how a gesture based infotainment system would perform in a driving context, and a convenient way to do an acceptance test of the system. Was the system something people would like to use?

The test was divided into two parts; learning the system and interacting with the system in a vehicle. These two parts made it possible to measure two different aspects of the system separately. It also allowed the participants to get past the initial learning phase and get familiar with how the system worked. While the participants got to practice on using the system, it also gave an indication of how easy the system was to comprehend and learn.

To measure the experienced workload while driving and interacting with the system, a modified version of NASA-TLX, with a less detailed scale, was used. This was used because it was an easy and cheap method to perform, but still giving us a concrete value of the workload to compare with the baseline workload when only driving. After the driving tests, semi-structured interviews were conducted to immediately get user feedback and opinions about the experience interacting with the system, while the participants still remembered most of it. Semi-structured interviews were used to allow for a discussion to be raised with each participant and for them not to feel interrogated, but relaxed and able to share their opinion. This while the interviewer still could keep the discussion to relevant topics and steer the discussion depending on what response the interviewee gave.

The rest of this chapter concerns the conducting of these methods.

4.4 Benchmarking

Already, there are vehicles available on the market that has integrated touchscreens in the center stack. As a part of the background research, a benchmarking session was performed to investigate what already was available and what is about to reach the market. The focus was to examine the systems from an interaction perspective.

To gather as much information as possible, 10 car brands were visited. Some of the brands had different infotainment systems in different models, resulting in information about 14 systems. Each system was examined, simply by using them and then analyse what was good and bad with the system. The analysis was not done to gather any quantitative data, but to get a understanding of how the touchscreens were used and worked. These systems were photographed and filmed while in use. When it was impossible to visit a retailer, due to the lack of nearby retailers, concept movies were also examined to get an understanding of the system. For a complete list of evaluated brands and models, see Appendix I.

4.4.1 Results

Figure 5 Infotainment system in Volkswagen Golf, Renault Clio and Volkswagen Sharan

First considering the visited brands' infotainment systems, three of the systems are shown in Figure 5. The findings here were that no system had completely abandoned physical buttons. Most systems use them in combination with a touchscreen, but some use physical buttons as the only way of interacting with the system, using an ordinary screen. The systems using a touchscreen use physical buttons for the menus of the infotainment system to navigate between the different functions. Sometimes it is also combined with a dashboard (a starting point in the system with shortcuts etc.). This dashboard works as a start screen when entering the system and to switch between applications/functions using touch interaction. However, some systems relied solely on its touchscreen for navigation and used physical buttons only for controlling the volume.

What was noticed was that all systems kept at least the volume rotary controller physical, for the driver to quickly be able to change the volume, or in some cases also turn the infotainment system off. The placement of the menu buttons varied mainly between being located below the screen or on both sides (left and right) of the screen.

Only one of the visited brands had a system that used a capacitive screen. The other brands instead used resistive screens, which often do not support multi-touch gestures. Capacitive touchscreens on the other hand will generally not react if the users wear gloves, but offers a superior experience with better sensitivity, response time etc.

There was also one model where there is an integrated 17” capacitive screen, placed in portrait mode, replacing all the ordinary physical buttons, including the volume button. (Teslamotors.com, n.d.).

4.4.2 Analysis

The general impression we got when visiting the ten brands was that the infotainment systems seemed not enough worked through. There were a few that stood out in a good way, but in general the quality of the interaction aspects and the overall design was low. Our focus was the interaction design of the system and they often failed to conform to interaction design practice. One example of this was the system, mentioned previously, where a shortcut in the navigation function lead to the radio, but there was no shortcut back to the navigation. This lead the user to a dead end, meaning excise work when having to enter the destination again. This is also an example where the system does not comply to the users' mental model, which is desirable. However, the thought behind the feature was good, but the execution needs to be revised.

The fact that all visited brands have kept some physical buttons makes it obvious that no good solution using only touch, has been found. There can definitely be advantages of keeping some physical buttons, for example, that they can both be localised and interacted with while keeping the eyes on the road, which is especially important in a driving context.

Considering the commonly used resistive screens in the systems, depending on which screen technology (resistive or capacitive) being used there are different pros and cons, but here the main consideration is the interaction aspect of them. Interaction-wise there is the main trade-off of being able to use gloves with a less touch sensitive screen (resistive) versus a screen where the user cannot wear gloves but get a better experience from using the screen (capacitive). The glove problem might be considered a small problem but when it is cold outside one does not gladly take the gloves off to interact with a screen. However, during the benchmarking we noticed a huge difference in user experience interacting with the different kinds of screens, favouring the capacitive one.

One notable manufacturer among the ones in this benchmarking is Tesla, replacing all the physical buttons with a large touchscreen in their Model S. Doing this gives them plenty screen real estate and the infotainment system seems to function more similar to a computer or a smartphone than an ordinary infotainment system. However, it is important to consider what these possibilities bring. In this system the driver can use a web browser to access the Internet, and websites that are not adapted to be viewed while driving, leading to high visual workload.

The main conclusion we could draw from doing this benchmarking was that many different systems and brands use touchscreens but the systems needed to be refined to be better suited in a vehicle and a driving context.

4.5 SCAMPER

After extensive research, the ideation phase began. One of the methods used to generate new concepts was SCAMPER. This was performed by analysing the infotainment system of a Volkswagen Golf, see Figure 6. The system was not chosen because of any characteristic attributes, but because it reflected the majority of infotainment systems and their distribution between touchscreen and physical buttons.

4.5.1 Results

The results of the SCAMPER session, which can be relevant for this master thesis, are presented below:

Substitution

In the substitution part there were many alternatives to using a rotary controller, physical navigation buttons, volume button, and individual fan buttons. All of these were found to be suitable to exchangeable to be controlled using gestures.

Adapt

In the adapting part it was suggested to adapt to Microsoft Kinect[7] or Leap Motion[8] which would incorporate free-form-gestures to control the functionality of the infotainment.

For complete results, see Appendix III.

4.5.2 Analysis

The motivation for performing this method was to develop new concepts. However, since re-focusing the project narrowed the scope, these types of methods for generating ideas to new concepts, were now irrelevant. Even so, some of the results were still considered useful, as presented in previous section.

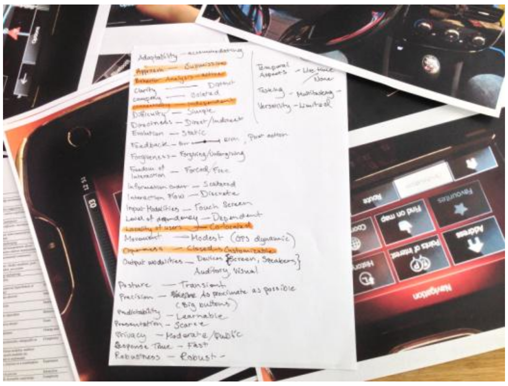

Figure 6 Performing SCAMPER on a Volkswagen Golf

Doing this analysis of the system was helpful to start considering other ways of interacting with the infotainment system, other than using physical buttons for common functions like fan or volume. However, it can be discussed why these functions are controlled using physical buttons. One reason can be that these functions are more critical to have easy access to control, and that cannot be neglected when developing new systems, based solely on touch- and gestural interactions.

4.6 Skewing

To generate additional concepts and develop new features, we analysed a second infotainment system, this time the infotainment system in a Renault Clio. Again, the motivation for choosing this particular system was that it was a good representation of how the current generation of infotainment systems worked. The analysis of the system was done using Lundgren's (2011) list of interaction related properties, and changed according to Lundgren and Gkouskos' (2013) ideation method, Skewing. The property list covers attributes related to behaviour, complexity, interaction etc. and helps analysing the system from many different aspects. Five of the properties were then chosen as the most prominent ones but only two

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[7] http://www.microsoft.com/en-us/kinectforwindows/
[8] https://www.leapmotion.com/product

were considered relevant for this thesis after re-focusing the project. These properties were *Approach* and *Openness*.

Lundgren's (2011) definition of *Approach* is *"which interactive stance the artifact takes* from *submissive* to being either *suggestive* or totally *dominant.* The system was at this point considered *submissive* and should thus be skewed towards acting dominant, telling the user what to do and how to do it.

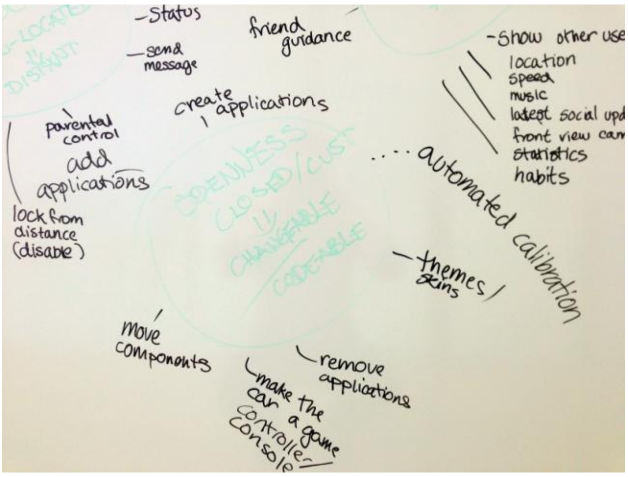

Figure 7 Skewing ideation on a whiteboard

The other property was *Openness*, which is *"how much an artifact allows the users to change it"* (Lundgren, 2011, p.8). The system was very much restricted in terms of what could be changed or customisable in the car. Albeit the ability to change things like sounds when interacting with the system, screen brightness and save favourite radio stations and destinations, the system was considered closed with only a few possibilities for customisation. Hence, the system should be skewed towards being *changeable* and in best case *codeable*.

All properties and towards what direction they should be skewed were put up on a whiteboard, see Figure 7. For each property as many features as possible were generated and written next to their corresponding property. At this point no concept or idea was declined for being too farfetched or not realisable.

4.6.1 Results

The following concepts are relevant outcomes from the skewing exercise. For complete information about the results, see Appendix IV.

Approach – Dominant

The infotainment system decides when it is safe for the driver to interact with it and will, in case the driver tries to interact with it in an inappropriate situation, warn the driver and prompt a message telling the driver to keep attention to the road and the driving situation instead of using the infotainment system, see Figure 8.

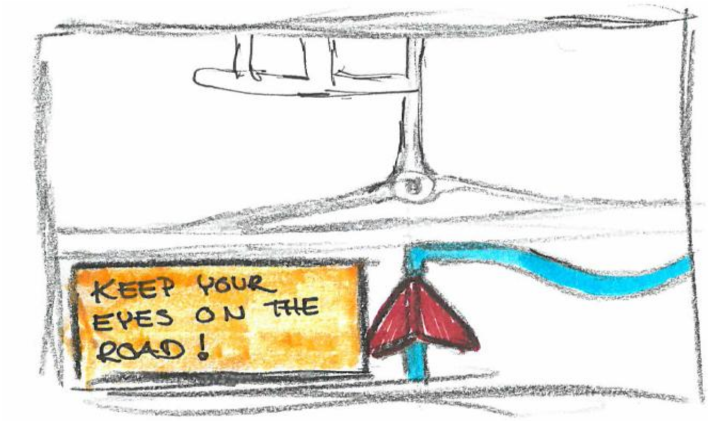

Figure 8 Concept drawing of attention warning

Openness - Changeable/Codeable

In this concept the users have full access to the car, meaning that information about the car can be retrieved and used, and the car can also be controlled through external applications. Here, everyone can create applications for their own car, to for example control the steering of the car, or the car's acceleration and brakes. These applications could also be available for others through an application market.

4.6.2 Analysis

The motivation for the use of this method was to develop new concepts, where parts might be considered useful in the final version. Due to the re-focusing of the project the concept generation fell out of scope and the thesis did instead focus on further investigating gestures.

Some of the results from the skewing session could however be considered relevant. A system that stresses the importance of attention to the road can still be useful. The system becomes an active guard to secure the drivers view on the road, hence minimising visual distraction. In the second concept the users could program applications to use in their cars, having full access to their cars. However, this is not suitable in a vehicle, but the underlying thought is interesting, that the user can program or customise own gestures or favourites. In order to create own applications for own vehicles, the manufacturers have to make sure that the vehicles are protected against exploits in the system.

What could be concluded from the skewing session was that it is good if the system can warn the driver if he or she becomes distracted from the road and that a changeable or even codable system could be interesting, but it has to be restricted.

4.7 Workshop

As a part of the ideation phase a workshop was conducted, aiming to generate design concepts and ideas for infotainment systems. There were eleven participants with mixed backgrounds, both with and without design as a profession but generally computer literate, in the ages of 18 to 37 years old participating in the workshop. Their experience with vehicles varied from having a driving license to designing infotainment system for vehicles. To encourage creativity Extreme Characters (Djajadiningrat et. al., 2000*)* was used. The participants were divided into three groups, combining different backgrounds providing several perspectives to the upcoming tasks. The extreme characters were chosen to enable and demand extreme types of interactions and burst the bubble of how things should look and work in a vehicle. Each group worked with one of the following characters:

- Yoda, from Star Wars
  - Abilities to move object using gestures, and the force
- Winnie the Pooh
  - Paws to interact with, having no fingers, and a childish mindset
- Rex, from Toy Story
  - Problematic short arms

With these characters in mind, the groups started to analyse characteristics, abilities and restrictions that described the character. Done with the analysis the groups begun the task of designing an infotainment system on for their character, having certain requirements to fulfil. The groups were instructed to incorporate a touchscreen in their solutions but were given a chance to motivate why they would not want to use one. For complete information and discussion about the workshop, see Appendix VI.

4.7.1 Analysis

One thing that can be noted when it comes to the participants' general approach designing infotainment system. For them it was hard to imagine a system completely without physical buttons. Even though the participants were considered to be relatively computer literate they had a hard time to envision how touch technology could enhance the experience and how it effectively could be compared to physical buttons and traditional in-vehicle controls.

All of the groups discussed the possibility of using voice command system and some also incorporated this somewhat into their design. Many of the participants considered a voice command system suitable for controlling the infotainment system. However, during the workshop the participants' experiences with such systems were discussed. Most of them were not satisfied with these systems, explaining how hard it is to be understood correctly by the system. Some of the participants also stated how these types of systems made them feeling silly while using them. The conclusion here was that even though an infotainment system can be controlled by voice commands, the controls of the system must have redundancy and not rely solely on voice interaction. This can also be applied to a system controlled by gestures. The controls have to be reliable to use and not to be misinterpreted by the system.

In general many of the groups' concepts incorporated multimodal interactions, combining gestures, voice, physical buttons and touch in different ways. The concept for Yoda involved free form gestures as the way of interacting, which can be powerful and useful. Albeit, the main concern when designing such systems is to map gestures intuitively to controls according to most people, not only to Yoda. Of course, some controls are easier to map than others, for example the volume can be increased by a raising hand or by pointing a thumb upwards. Still even in this, relatively simple, example there are many ways to map the control while keeping it rather intuitive.

In the infotainment of Rex, the design highlights the issue of reaching for the screen versus having a device placed closer to the body, enabling interaction closer at hand. Even though it is outside the scope of this thesis, it is an interesting topic and there are already systems which are controlled by a touch pad rather than a touchscreen for a closer interaction, for example Audi (n.d.).

Winnie the Pooh's interface symbolises the simplicity which is required when designing infotainment systems. The task should not be unnecessarily complicated, neither interaction-wise nor decision-wise, especially not while the car is moving.

Regarding the characters used in the workshop. Each character was chosen to highlight extreme attributes with a chance to generate ideas that could also be used in a similar situation, though not as extreme. As an example, Rex has very short arms, which was why he was chosen. The intention was that the group who worked with him should come up with a possible solution for the placement of the touchscreen. Instead the whole car was changed to fit his needs, which did not result in any solution usable for us in this thesis. Yoda was chosen as a character that could use his force, which was supposed to encourage the group to consider free-form gestures, how they would work and what gestures one could do. Most of the gathered data was not as useful as we had hoped for. Albeit, there were ideas about highlighting the area of interaction and its placement that could be useful to further research with free-form gestures.

Lastly, Winnie the Pooh was chosen because of him lacking fingers, except for his thumb. Our goal with choosing him was to generate ideas about gross gestures that would not involve caring about a specific number of fingers, but gestures using a palm or "all fingers". Instead many ideas were generated with emphasis on Winnie the Pooh's character and how the system would adapt and suggest actions for him. This could be considered very similar to Google Now [9] and how it adapts and suggests routes and actions after analysing one’s behaviour and daily pattern. Albeit the good intentions, no real suggestions for gestures were elicited and was thus not useful after re-focusing the thesis.

4.8 Stating the objectives

Reaching this point in the project it became evident that the original scope had been too broad, considering the resources available during the project, like time and knowledge. To be able to narrow the scope, the important features had to be identified not to lose the core of the project. This was done with the help of the method *Stating the objectives*. The outcome was a much more focused thesis, which should research gestures and to develop guidelines for in-vehicle infotainment systems. These guidelines specifically apply while driving, for further reading about the re-focusing of the project, see chapter 4.2.

4.9 Questionnaire about importance of the feature controls in the car

Every driver has their own preferences when it comes to features in the vehicle. This survey aimed to find what controls, controlling different features in a vehicle, people wanted fast access to.

The survey was digitally distributed yielding over 100 participants between the ages of 23 and 62 years old. The participants included non-drivers to drivers who have had driving license for more than 10 years, who travel by car every day to a few times a year. The aim was to reach a broad audience for the survey, and even though a few of the participants did not have driving license, they were still considered relevant, having experience from being passengers and have thereby used existing systems. They were asked about the importance of easy/fast access to controls and rate it on a scale 1-4, going from “Not important” to “Critical”. The questions and more detailed results can be found in Appendix V.

[9] http://www.google.com/landing/now/

4.9.1 Results

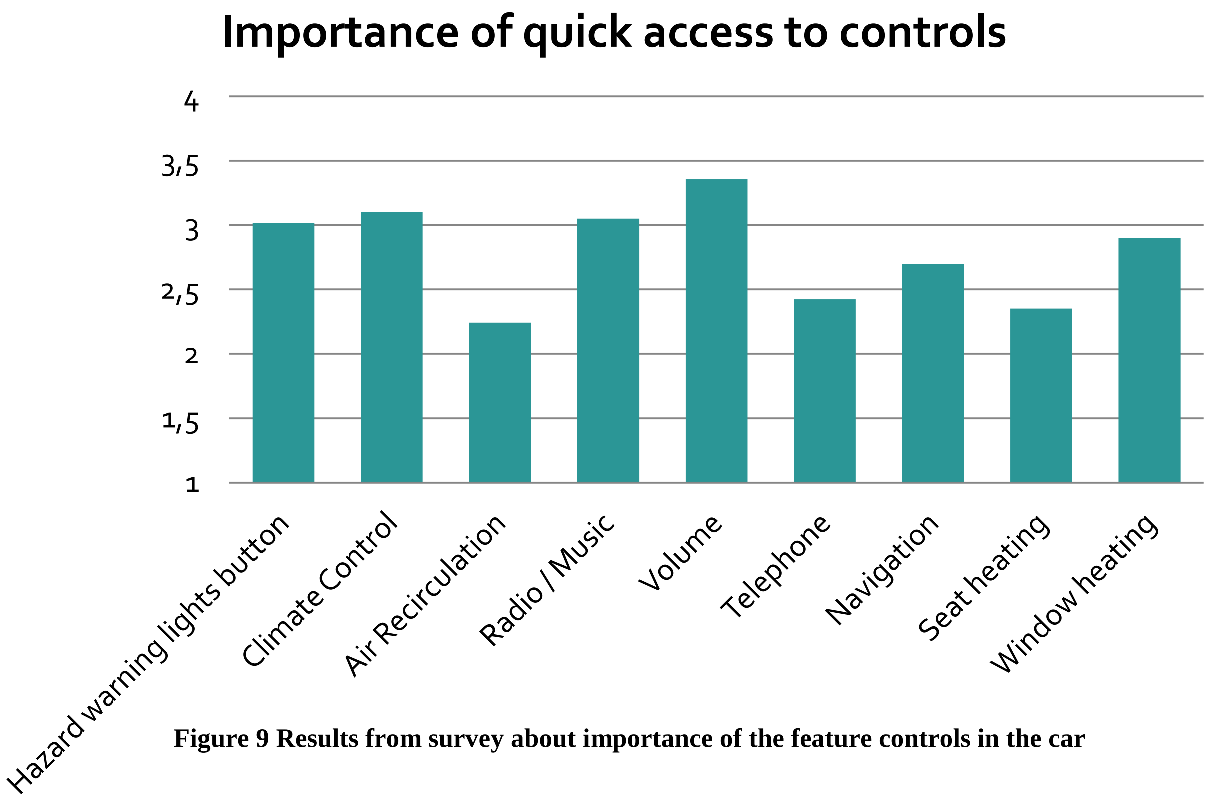

Figure 9 Results from survey about importance of the feature controls in the car

The results in Figure 9 show that the importance of the controls is highly individual, and the opinion about the controls of the requested features varies a lot. Based on the calculated average rating, some controls seem to be more critical to have quick access to than others. For example having quick access to volume and climate was considered more critical than the controls for air recirculation and seat heating. One participant commented that *"things, such as the hazard warning lights button, that are used only under certain conditions can afford to be secondary"* (Appendix V) and rated it as 2 on the scale whereas other participants rated the hazard warning lights button as 4, meaning that quick access to the control is critical.

4.9.2 Analysis

The survey was done aiming to get an understanding of which controls drivers thought were necessary, gave useful information about the topic. As predicted, it was clear that the participants had all different opinions of which controls they wanted to have quick access to. Some of the participants also gave suggestions about other features which they found important, but were not listed in the survey. Most of these suggestions concerned features which were not considered to be integrated into the infotainment system, and were thus not included in the following research. This was generally not considered a problem for us, but perhaps if we could had given more background information to the survey about what we worked with we might have gotten more relevant comments.

Also, the formulation of the survey could have affected the results. Even though trying to make it clear that it was access to controls they should be rating and not the actual feature itself, some of the participants might have not read the instructions thoroughly and might have missed that information. The results of a survey where the participants should rate the importance of the features rather than the access of the controls of the features would probably yield different results.

The answers could also be dependent on a context, for example it is more important to control the window heating when it is cold outside than when it is warm. A specific context was not provided even though it might have changed the results. However, not providing a context might yield a more general result, but having the disadvantage of different interpretations of the questions.

Another thing that might have been preferable was to exclude users without a driver's licence and only get answers from participants with real experience from using existing systems while driving. Even though this would be preferable there were only five participants of over 100 participants who would have been excluded, thus the results would not have changed significantly.

What surprised us was the rating of controlling telephone (average rating of 2.4). An explanation to this could be that the participants had no or little experience with integrating their mobile phones into their cars. Perhaps, if they got used to always having access to their phone through the infotainment system, they would rate it higher.

To summarise the survey it can be concluded that the drivers seems to agree that quick access to volume, as well as climate, radio/music and the hazard warning lights, was critical. Least important, was access to air recirculation together with seat heating. However it should be noted that neither of these functions can be considered completely unimportant based on the rating average where they both had a rating above 2.2.

4.10 Gesture mapping

The result of the previously conducted survey was used as a foundation to the gesture mapping, where studies were conducted to map different controls of features and actions in a vehicle. The gesture mapping had three iterations to map gestures to actions. The first one was to let the users themselves come up with gestures for controlling different actions. The results of this were refined in a second iteration, where the users got to map actions to predefined gestures. The actions used in the second iteration, were actions that previous iteration did not find intuitive mappings for. This lead to the development of two concepts, which were further iterated a third time by letting the users map the actions back to their corresponding gesture. For complete information, statistics and forms, see Appendix VII.

4.10.1 First iteration

To gather information about peoples' preferences and what gesture they considered natural to map with different actions a user test was conducted. The actions used were mostly based on results from the survey of which controls the users considered important to have fast access to, but with assumptions made that certain features, such as the hazard warning light, still should have dedicated physical buttons and thus not be included. The two actions which the previous study showed to be most important for the drivers were used, namely music and climate control. It was also included to control system specific actions since this was included in the scope of the thesis. Additionally, to examine peoples' attitude and how they welcome new technology, such as touch interfaces, they were asked about owning tablets and simply whether they felt comfortable using gadgets. The user tests were done with 16 participants in the ages 22-63 years old, different backgrounds and with different experience of using technology.

The test was conducted as follows:

1. The users were asked three questions about themselves:
   a. How old are you?
   b. Do you own a tablet in private?
   c. How are your feelings towards using new technology such as touchscreens?
2. The users were asked to map the following actions to whatever gesture they thought suitable:
   a. Volume
   b. Radio/Music: play/pause
   c. Radio/Music: next/previous
   d. "Home"
   e. Show all applications
   f. Switch between applications
   g. Quit an application
   h. Answering a telephone call
   i. Quitting a telephone call
   j. Open the favourite application
   k. Climate control: Temperature
   l. Climate control: Fan speed

Using a drawing application on an iPad, the participants were encouraged to draw or describe whatever solution they came up with. No solution was stupid, too hard or too simple. They did not have to think about gestures interfering with each other, even if many did so anyway. However, the participants were still asked to describe thoughts about the origin of the gesture and what was expected to happen while performing a gesture. Figure 10 shows one of the protocols from the first iteration gesture mapping.

Results

No matter age or experience, most people answered that they considered themselves positive to new technology and was intrigued by the thought of using touchscreens in a vehicle. When summarising the results of the gesture mapping tests it was concluded that a few actions had an intuitive mapping to a certain gesture that most participants agreed on. Other had a few options with different conceptions and symbolic means for what the gesture corresponded to in the physical world. Lastly, a few had almost no similar suggestions, hence needed further research before being implemented and tested on an interactive prototype.

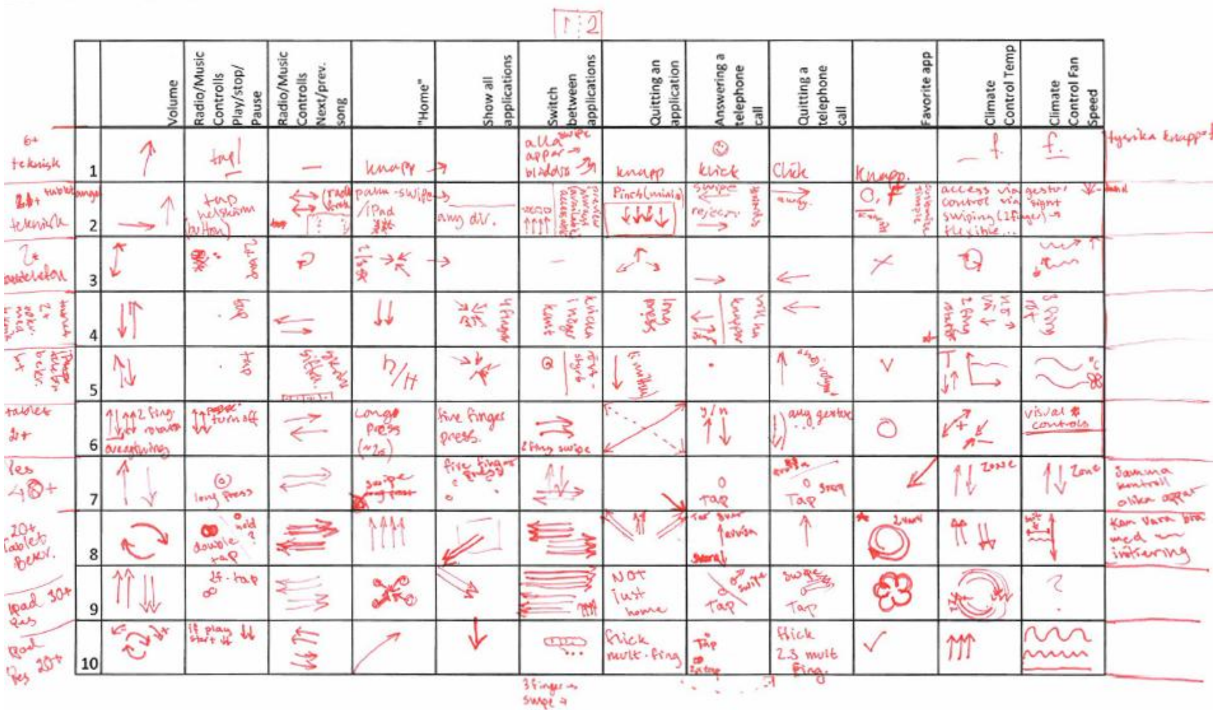

Figure 10 Protocol from the first iteration of gesture mappings

Defined gestures

The following actions and gestures are the initial ones that most participants to some extent all agreed on.

Volume

When being asked about how they would like to control the volume there were mainly two proposed gestures. The most popular gesture was simply swiping up and down with either one or two fingers. Some people motivated using two fingers with the otherwise possible interference with other interactions in the current application. Others solved this issue suggesting that there could be specific zones for different features.

The second gesture was a rotating gesture, imitating the movement one does when turning the volume up or down using a volume knob. Albeit the strong connection between controlling the volume on a stereo, using a rotating knob, and the gesture, it was considered a too complex gesture while driving.

Music / Radio - Play / Pause

The play/pause action was by most people mapped to an easy, short gesture. Again arguing that one finger would interfere with actions in the application currently in use, two finger-tap or double tap was the most common suggestion.

Music / Radio - Next / Previous song

Skipping to next or previous song in a playlist or switching among the preset radio stations, is one of the gestures where most test persons agree with each other and map the action to the same gesture. In this case the gesture most intuitive would be to use a two finger-swipe from side to side. However, there seems to be no agreement on what direction corresponds to what

action (next or previous). What can be concluded when asking about this is that there are two groups with different conceptions. One group visualises their gesture as moving an actual object with the swipe, hence wants the gesture to go from right to left to skip to next song. The other group have a more symbolic approach and see themeselves drawing the direction they want to skip. Hence, their gesture instead goes from left to right.
Browsing other systems, one can tell that there seems to differ between generations. With the introduction of iOS and Android, the agreed convention is to approach this as if one is actually manipulation an actual object.

Switch between active applications
Similar to how people wanted to change track, switching between active applications would be done using three, or more, fingers to swipe either from side to side or up and down. Even though it was not a unified answer one could already conclude that this would be a proper gesture for the purpose.

Answering / declining / ending a phone call
To answer a phone call mainly two gestures were suggested. Most of the participants assumed that the system would (and wanted it to do so) display a picture of the person calling. One could then simply tap the image to answer the phone call or flick the image away to decline it. Or the user could instead, similar to the solutions used in iOS and Android, swipe in one direction to answer and the other direction to decline it.
Being in a phone call and wanting to end it, most participants suggested that it should be as simple as answering, just a tap.

Semi-defined gestures
Some of the actions the participants were asked to perform had multiple possible gestures mapped to them. Often the proposed gestures were exact copies or very inspired by already existing systems used by the participant. These semi-defined gestures would need further definition and since no clear pattern could be elicited, the most prominent or seemingly most intuitive gestures will be used and tested further.

One such gesture was going straight to “home”, which was compared to the home screen in iOS or the desktop in Android. What was common for many of the suggested gestures was that it was thought of as a *bigger* gesture, involving more fingers or the flat of the hand. Among the proposed gestures were four finger-swipe up and three, four and five finger-pinch.

Similar to home was also “Show all applications” which was interpreted as the same as home by many and thus had very similar gestures suggested.

Undefined gestures
Although not many, there were still actions that got almost as many different suggested gestures as there were participants. One such action was controlling the climate in the vehicle.

There were also many different conceptions for how one should quit an application. Some participants wanted to do a “tap and hold”, while others wanted to swipe away (up or down), or do a pinch with multiple (three or more) fingers.

Lastly, it was very hard to find a gesture to immediately access a favourite application that most people agreed on. A few people suggested that one could draw a circle, simply because it was quick and easy to do so. Other suggestions were diagonal swipe from top to bottom corner, a five finger-pinch or using specific zones where one should tap and hold.

Analysis

What can be concluded from this user test is that many people have a hard time thinking *outside the box* and think further than of already existing solutions, gestures they already know exist and how to perform them. This was true for most of the participants. Despite having different experience of using gadgets and technology and despite their own attitude towards new technology, most gestures and actions were direct copies or similar to gestures used in Android or iOS. Many multiple finger-gestures were also similar or exact copies of gestures used when using a touchpad in modern versions of Apple's OS X[10].

Perhaps this is not a problem. Considering the driving context, an in vehicle infotainment system is not a proper system for users to start learning new gestures. With touch interfaces entering the market on a larger scale, the present idioms people have gotten used to are no longer as relevant as on a desktop computer. Hence, there is a need for new idioms and new ways of interacting to be incorporated and learnt. However, forcing someone to learn these idioms in a driving context would be very unsafe. A better solution would instead be to develop and iterate these idioms and gestures on less critical devices, such a smartphones and tablets, and later incorporate the ones people seem to find most intuitive and the ones most widely spread into the infotainment systems.

The user would then recognise or know the gesture and thus also know what to expect when performing this action in a vehicle as well.

4.10.2 Second iteration

The initial gesture mapping found six actions where most people could agree on a specific gesture and thus found intuitive. However, it also gave an indication on which actions could intuitively map to a gesture (metaphoric), and which had to be learned (idiomatic). To find gestures that most people could agree on, even though they might not have a natural mapping to gestures used in the physical world, a second test was performed. This time only the remaining six actions, the ones without an intuitive mapping, were included. Together with the six actions, fifteen gestures were listed. The fifteen predetermined gestures did all

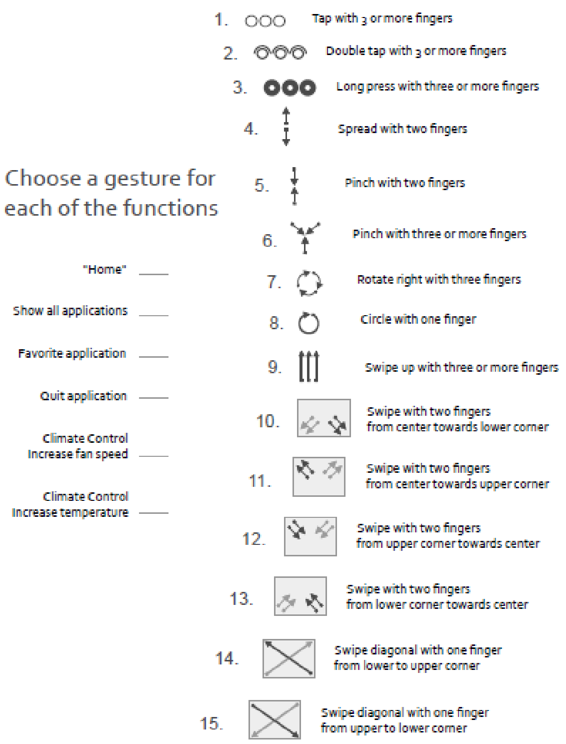

Figure 11 Form used during the second iteration of gesture mapping

[10] http://support.apple.com/kb/ht4721

originate from previous iterations in the process. 23 persons with mixed background and with different experience of using technology, in ages between 23-61 years old, were then asked to choose one of the fifteen gestures for each of the six actions. The same gesture was not allowed to be used more than once and the participants were asked to think aloud and describe their thoughts when filling out the form, see Figure 11.

With previous knowledge in mind, the participants were again asked whether they owned a tablet or smartphone. This was done to further investigate how their previous experience affect their opinion of what a certain gesture is expected to represent and whether this knowledge helps imagining how other gestures could be used, or restrict the participants from thinking independently.

The actions each participant was asked to map, were the following:

- Home
- Show all applications
- Favourite application
- Quit application
- Climate control: Increase fan speed
- Climate control: Increase temperature

Results

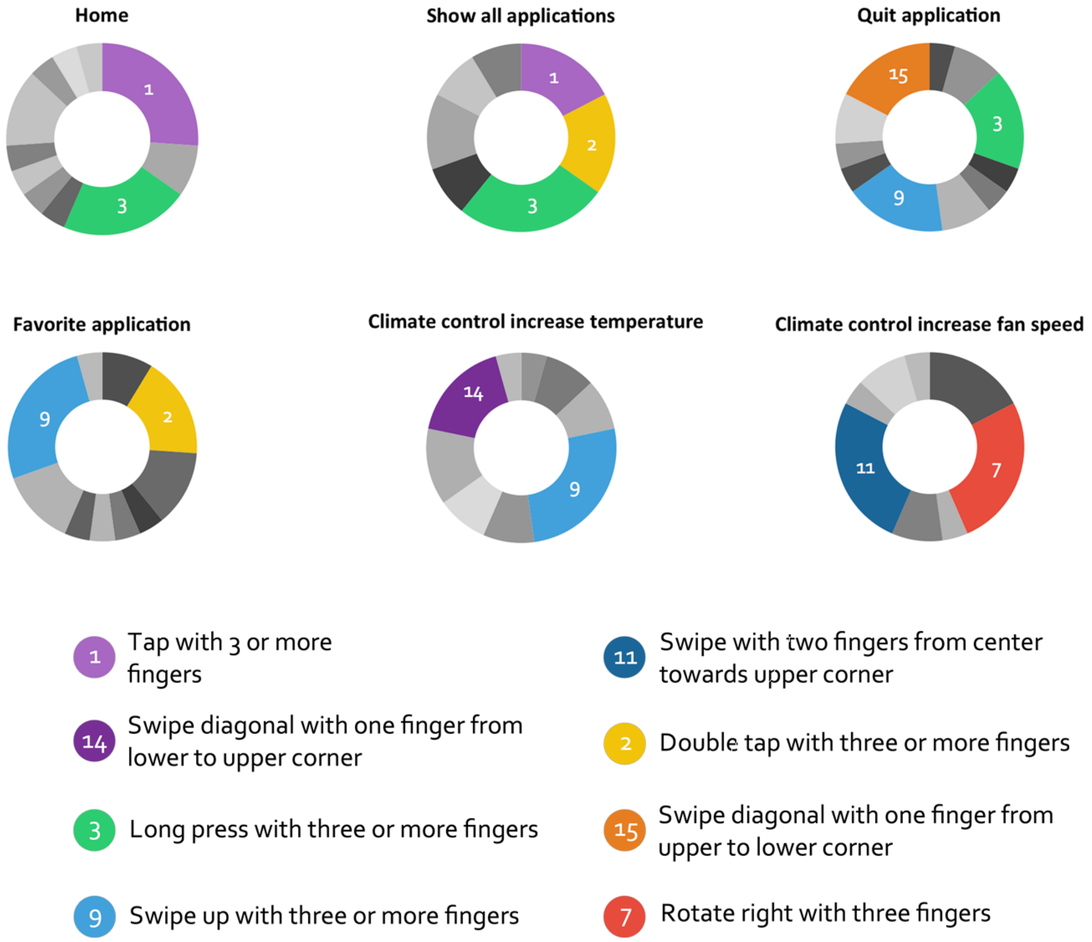

Figure 12 Diagrams showing the results from the second iteration of gesture mapping. The most popular alternatives for each action is highlighted and numbered corresponding to the legend underneath, these numbers also refers to the numbering of the gestures in Figure 11.

The results from the second iteration of the gesture mapping are shown in Figure 12. The diagrams show the distribution of the different gestures, with the coloured areas being the most popular gestures for the specific action and thus the ones most suitable, from the users' perspective. These gestures are:

Home

- Tap with 3 fingers

Show all applications

- Tap with 3 or more fingers
- Double tap with three or more fingers
- Long press with three or more fingers

Quit application

- Long press with three or more fingers
- Swipe up with three or more fingers
- Swipe diagonal with one finger from upper to lower corner

Favourite application

- Double tap with three or more fingers
- Swipe up with three or more fingers

Climate control increase temperature

- Swipe up with three or more fingers
- Swipe diagonally with one finger from lower to upper corner

Climate control increase fan speed

- Rotate right with three fingers
- Swipe with two fingers from centre towards upper corner

Analysis

What could be concluded from the results of the second user test was that many participants considered *home* and *show all applications* to be similar or even the same thing. Also, quitting an application was by some participants considered very similar. Hence, all three of these actions had a long press with three or more fingers as one of the most popular gestures. This perception is most likely taught from using a smartphone or a tablet. Neither of the popular operating systems does rely on the user quitting applications but does instead encourage users to change their old approach from using computers, where one quit applications that are not in use.

Closing applications did also have the suggestions that one should either swipe upwards (which some mentioned when asked about that it could as well be downwards) or swipe diagonally from an upper to a lower corner, like drawing a cross (often used as a symbol for closing applications and windows). Generally one could argue that quitting an application, meaning not just minimising but quitting it, should not be as quick and easy as going home (only minimising the application). Quitting an application should never be done by accident. Both swiping diagonally and swiping with three or more fingers are gestures that the user most likely will never perform by accident, which a short tap or a long press could be, and are thus both suitable gestures that will be performed only when the user intends to.

The gesture for opening up one’s favourite application seemed to be one of the most difficult to find an intuitive gesture for. Since the action simply is a shortcut to something, thus nothing that is possible to achieve in the physical world, there is no natural gesture to mimic, which makes this gesture purely idiomatic and something that must be taught and learnt. This gets clear when observing the participants leaving the favourite application gesture to decide after pairing the other actions with suitable gestures, and then simply pick the gesture they liked best among the remaining ones. An analogy would otherwise be how an up or down swiping movement could be considered a direct transfer of a musicians mixing console with its sliding volume controls.

A similar behaviour could be observed among the participants when deciding what gesture to pair with the climate actions. Most participants suggested that the two gestures controlling temperature and fan should preferably be similar. However, with the fifteen gestures provided, many participants did not find a solution where the two actions could have similar gestures.

4.10.3 Concept development

With the results from the second iteration as a foundation, two concepts were developed. One concept, which relied solely on user input and their preferences, except for adjustments to avoid multiple actions being assigned the same gesture, and one single rule, that no gesture should require the user to use more than three fingers. All gestures using more than three fingers would thus be considered the same as their three finger equivalent.

Users' concept - Action-gesture-mapping

Telephone

- Answer a telephone call: *Tap with one finger*
- Decline a telephone call: *Flick with one finger*

Music

- Volume: *Swipe up / down with two fingers*
- Play / pause: *Tap with two fingers*
- Next / Previous: *Swipe left / right with two fingers*

Climate

- Fan speed: *Rotate with three fingers*
- Temperature: *Swipe up / down with three or more fingers*

System

- Home: *Tap with three or more fingers*
- Show all applications: *Long press with three or more fingers*
- Switch between applications: *Swipe left / right with three or more fingers*
- Favourite applications*: Circle with one finger*
- Quit application: *Swipe diagonal with one finger from upper to lower corner*

The second concept's foundation was also based on the user input. This time however we relied on our own experience as interaction designers to refine the concept, aiming for coherency by applying an underlying pattern or logic for how gestures and actions were coupled. The result was a pattern where two fingers controlled music and volume, three fingers controlled climate, and four fingers were used for system specific actions. Coherency can often help the users to comprehend the complex by providing an inner logic, a solid ground that the rest builds upon. One of the most prominent profiles within usability, Nielsen (1994), lists coherency as one of the more important usability heuristics. Within HCI, coherency is often discussed as being the basis for a functional system (Beyer & Holzblatt, 1998). As Lundgren suggests:

> *"Coherency - in its widest sense - is to strive for harmony and unity in design using some kind of underlying rationale for design - be it based on mathematics, adaption to functionality, personality or something else."* (Lundgren, 2010, p. 101)

Designers' concept - Action-gesture-mapping

Telephone - One finger

- Answer a telephone call: *Tap with one finger*
- Decline a telephone call: *Flick with one finger*

Music - Two fingers

- Volume: *Swipe up / down with two fingers*
- Music - Play / pause: *Tap with two fingers*
- Music - Next / Previous: *Swipe left / right with two fingers*

Climate - Three fingers

- Fan speed: *Swipe left / right with three fingers*
- Temperature: *Swipe up / down with three fingers*

System - Four fingers

- Home: *Long press with four fingers*
- Show all applications: *Swipe up with four fingers*
- Switch between applications: *Swipe left / right with four fingers*
- Favourite applications: *Double tap with four fingers*
- Quit application: *Swipe down with four fingers*

4.10.4 Third iteration

The two developed concepts were based on the conclusions from the preceding user studies. To further evaluate these concepts and confirm the mappings of the gestures, a third iteration gesture mapping was conducted. The test involved 27 participants in mixed ages, different backgrounds and with different experience of using technology. It was set up having 14 participants testing the Users' concept and 13 participants testing the Designers' concept. The gestures of the concept were listed in a random order in a form, same order for each participant though, and the task for the participants was to map the corresponding gesture for each of the listed actions.

Results - Users' concept

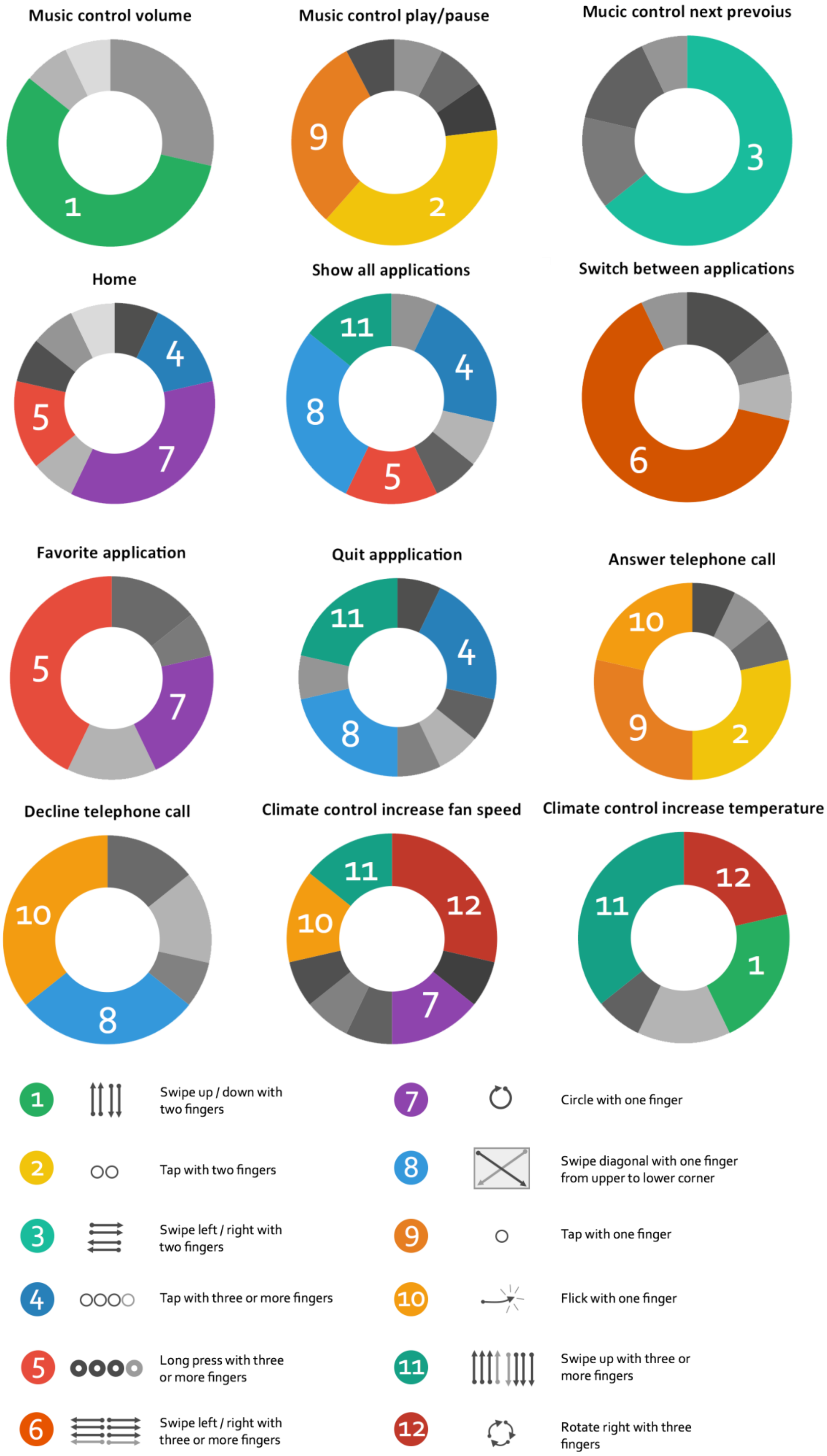

Figure 13 Results from the third iteration of gesture mapping of the Users' Concept. The most popular alternatives for each action is highlighted and numbered corresponding to the legend underneath

The users' concept was all based on the users' opinions and was tested by 14 participants. Figure 13 shows the results and the results are also listed below. The actions are listed together with the most popular mapped gesture/-s:

Volume

- swipe up or down with two fingers

Playing/pausing music

- two finger tap
- one finger tap

Changing music or radio station

- swipe left or right with two fingers

Answering a telephone call

- one finger tap
- two finger tap
- flick with one finger

Decline a phone call

- flick with one finger
- swipe diagonally with one finger from upper to lower corner

Fan speed

- rotate left or right with three or more fingers
- circle with one finger
- flick with one finger
- swipe up or down with three or more fingers

Changing temperature

- swipe up or down with three or more fingers
- swipe up or down with two fingers
- rotate left or right with three or more fingers

Switching between applications

- between applications swipe left or right with three fingers

Go to home

- circle with one finger
- tap with three or more fingers
- long press with three or more fingers

Show all applications

- swipe diagonal with one finger from upper to lower corner
- tap with three or more fingers
- long press with three or more fingers
- swipe up or down with three or more fingers

Favourite application

- long press with three or more fingers
- circle with one finger

Quit application

- swipe diagonal with one finger from upper to lower corner
- swipe up or down with three or more fingers
- tap with three or more fingers

Analysis - Users' concept

This was the concept which was all based on the users' opinions. It can be seen that some of the gestures had a more intuitive mapping than other. The gestures for volume (swipe up or down with two fingers), changing music or radio station (swipe left or right with two fingers), or switching between applications (swipe left or right with three or more fingers), most of the participants seemed to agree on. These gestures were also the same as intended in the concept. The gestures for playing/pausing music (two finger tap) and answering a telephone call (one finger tap), there were disagreements regarding how many fingers to use, but the basic gestures were the same. These gestures are again same as intended in the concept. Considering how to decline a phone call (flick with one finger) there were two popular gestures, where one of them conformed to the concept and the other one was to swipe diagonally with one finger from upper to lower corner.

To control the fan speed (rotate left or right with three or more fingers) the participants had a hard time agreeing on how many fingers to use. One proposal conforms to the concept, and the alternative gesture (circle with one finger) resembles, to some extent, the gesture used in the concept. Most of the participants agreed on the basic gesture for changing temperature (with the reservation of how many fingers to use) and both gestures to control climate conforms to the concept.

The largest confusion was the gestures to control the system actions. There is one, however, that stood out as being natural to most of the participants, namely the three or more finger swipe to change application. The other ones were hard for the participants to agree on.

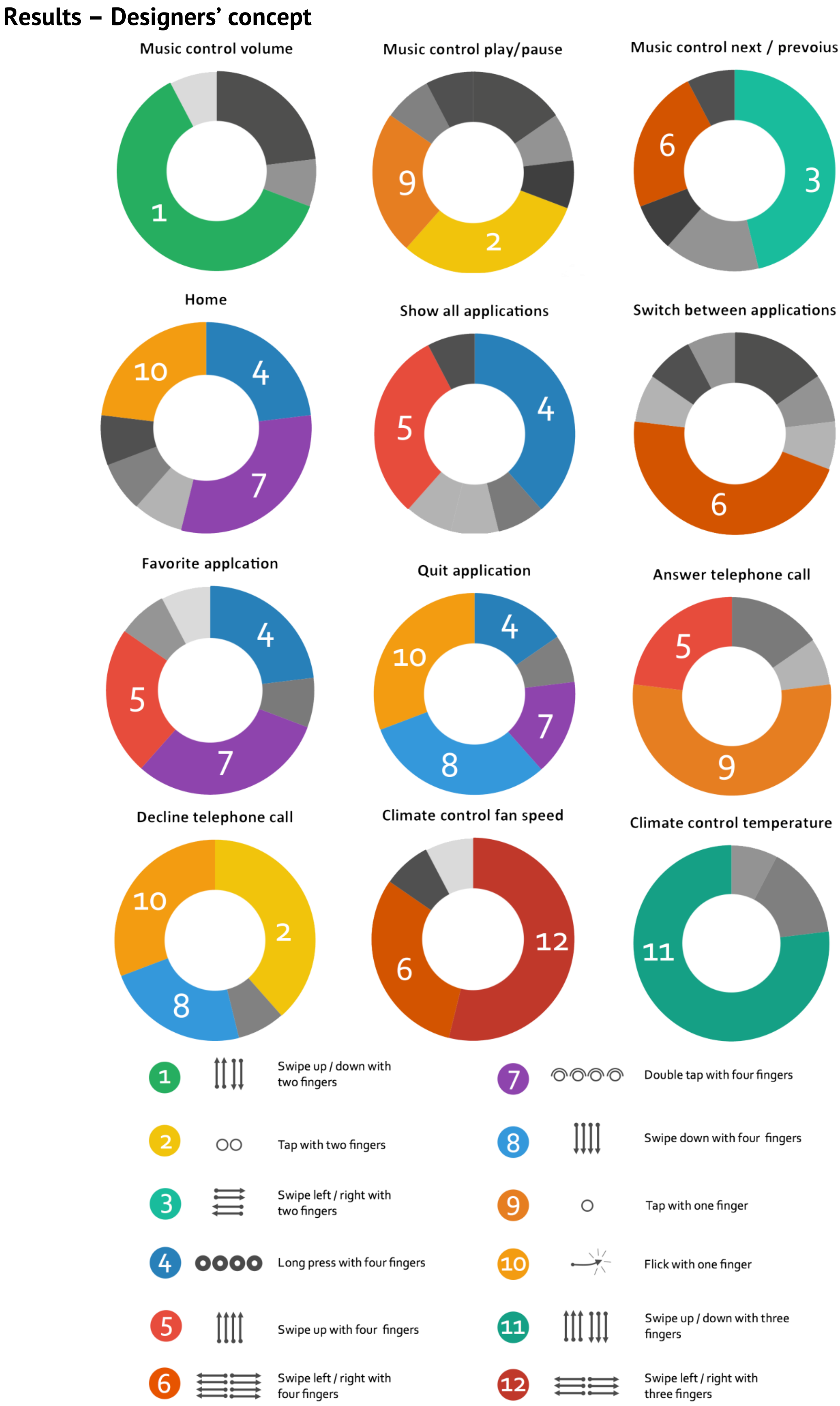

Figure 14 Results from the third iteration of gesture mapping of the Designers' Concept. The most popular alternatives for each action is highlighted and numbered corresponding to the legend underneath

This concept originates from the user studies but is refined to have an underlying logical structure and was tested by 13 participants. In the results below are the actions listed together with the most popular mapped gesture/-s, and is also shown in Figure 14:

Volume

- swipe up or down with two fingers

Playing/pausing music

- two finger tap
- one finger tap

Changing music or radio station

- swipe left or right with two fingers
- swipe left or right with four fingers

Answering a telephone call

- one finger tap
- swipe up with four fingers

Decline a phone call

- tap with two fingers
- flick with one finger
- swipe down with four fingers

Fan speed

- swipe left or right with three fingers
- swipe left or right with four fingers

Changing temperature

- swipe up or down with three fingers

Switching between applications

- swipe left or right with four fingers

Go to ”home”

- double tap with four fingers
- long press with four fingers
- flick with one finger

Show all applications

- long press with four fingers
- swipe up with four fingers

Favourite application

- double tap with four fingers
- long press with four fingers
- swipe up with four fingers

Quit application

- swipe down with three fingers
- flick with one finger
- double tap with four fingers
- long press with four fingers

Analysis - Designers' concept

This concept was developed based on the conducted user studies but with improved coherency by applying an underlying logical pattern. The tests showed that the participants did not always find this pattern, but even so, some of the gestures were mapped correctly by most of the participants. This indicates that the mappings of these are more intuitive. Also in this concept most of the participants agreed on the gestures to control volume (swipe up or down with two fingers), changing temperature (swipe up or down with four fingers) and switching applications (swipe left or right with three fingers). Again all of these gestures are the same as in the concept.

As in the Users' concept there were some actions that the participants did almost agree on, the difference was how many fingers to use. The basic gestures were the same, which indicates that most of the participants think that the basic gestures were intuitive. However, the question regarding how many fingers to use was more ambiguous. The actions most agreed on were play or pause music (two finger tap), change music (swipe left or right with two fingers), and changing fan speed (swipe left or right with three fingers).

Even though the participants did not agree on how to answer (one finger tap) or decline (flick with one finger) a telephone call, it was possible to conclude that the two actions should have gestures that were connected to each other. The most popular alternative gesture to answer was swiping four fingers up, and to decline, tapping with two fingers or swiping down with four fingers. All of these alternatives have at least some attribute in common with the gestures used in the concept or among themselves. For example, swipe with four fingers up to answer and four fingers down to decline, use the same number of touch points, even though direction differs.

Same scenario as with the Users' concept, four (out of five) gestures controlling actions on system level, were problematic. However it can be seen from the tests that many of the alternatives suggest using four finger gestures, but the mapping seems confusing.

Conclusion - Third iteration

The aim for this test was to evaluate the concepts and confirm the mappings of the gestures with the actions. It can be confirmed that some of the gestures have a more intuitive mapping to their action while others are more ambiguous and require more learning.

4.11 Expert evaluation

As a natural step in our design process, the two different concepts needed to be evaluated. The concepts which were elicited from user tests and developed into two different high fidelity prototypes; The Users' concept, which relied solely on input from user tests and interviews, except for interference between gestures that had to be solved, and the Designers' concept which also was based on data from the user tests and interviews, but with us as interaction designers having refined it aiming for coherency. Since the whole process thus far had relied much on intended users and their input, we considered it useful to involve people with a better understanding of interaction design and usability, which could evaluate the prototypes more thoroughly and analyse it to see where things break and propose possible solutions to each problem.

Each evaluation was conducted with a group of four people, all students from the Interaction Design and Technologies program at Chalmers University of Technology, doing their master thesis within the topic of touch interactions, and were both audio recorded. A picture from the first session can be seen in Figure 15. The groups were both asked to answer a questionnaire, which inspired by NASA-TLX, but changed according to our own preferences and better raise relevant discussions. Each group was supposed to fill out the questionnaire together and was thus encouraged to discuss each attribute of a gesture to, in the end, agree on grading the prototype on a 5-point scale. The questionnaire included the following questions:

- What is the overall grade for this gesture and its mapping to the specific action?
- How hard was the gesture to perform, physically?
- How mentally demanding was the gesture?
- How metaphoric do you find the gesture to be?
- How successful were you in accomplishing what you were asked to do?
- Did you get the response/feedback you were expecting?

Although the groups were asked to fill out the questionnaire, the final grading that the group agreed, or did not agree on, was not as important as encouraging the evaluators to discuss all aspects of every gesture and its mapping. The evaluators were forced to explain to each other why they considered one thing easier than another and from where one's associations origin. Hence, this chapter will not present results from the questionnaire but rather highlight comments and discussions that occurred during the sessions.

4.11.1 First session - Users' concept

Figure 15 One of the expert evaluation sessions

One of the discussions that occurred during the session was about the concept itself. One of the evaluators asked whether it was a good idea to have many different gestures doing different things. He instead suggested that one could use a screen for each of the action groups. However, we considered this to be the same thing as having a specific application to control the feature, which naturally would exist in a real system as well as in the prototype. What the thesis instead tried to achieve was to replace physical buttons and controls that the driver can use while driving, without breaking the workflow within navigation, for example. By removing the universality of each gesture, we argue that one would defeat the purpose of adding the gestures in the first place.

Trying to highlight that it could be problematic with many gestures, the group also suggested that one could be able to activate different modes depending on what the user would like to change. Similar to opening up an application, which then allows a limited number of interactions, one could activate a mode and then use a set of gestures. This approach has been mentioned and considered before in the initial gesture mapping process but was something mentioned by only a few and thus considered not as intuitive as direct control. This approach would allow fewer gestures to control more features, except for the fact that there has to be an initial activation of each mode. However, we argued that it would be more effective and fast with a gesture that had immediate effect. The expert group preferred a few simple gestures controlling only a few features, instead of adding more complex gesture to be able to control more features or actions. However, since activating a mode requires an extra gesture, the total number of gestures would in the end be about the same, and thus, we would again prefer direct control.

A general potential problem with the gesture concept that were raised was the fact that the user might trigger something by mistake, simply by doing a gesture wrong or by touching the screen by mistake. This is of course an issue that needs to be addressed when designing what features or actions that will be controlled and what gestures to use. It also concerns the physical placement of the screen, which this thesis did not focus on. Lastly, the group highlighted the importance of a logical system for how the gestures relate to each other. The experts were also shown the Designers' concept which received better feedback since they considered it to be based on a prominent pattern that would be easier to learn. The evaluators also argued that one should make use of already known conventions and gestures from other devices. If the users already know a gesture for achieving the same action as intended, then that gesture should be used as well.

4.11.2 Second session - Designers' concept

An initial comment given by the evaluators was that it was problematic with the prototype giving visual feedback when changing the climate. This has been a general problem, since there was no possibility to integrate the prototype in a vehicle. One solution that was suggested was simply to control the volume of a fan sound and thus get the auditory feedback instead.

A general comment that was mentioned several times was that there should always be sound acknowledging the users' actions. This would then give the users the necessary feedback to know that they have succeeded with the gesture and could help avoiding the drivers looking at the screen while driving. A comparison was that when changing the volume in OS X, the operating system used in Apple computers, there is a short sound acknowledging each press on the volume key. In similarity, there could be a sound indicating when volume has been changed one tenth of total, which would help users get a sense for how much they are changing the volume. The group suggested that the same approach could advantageously be used for most actions and thus confirming each gesture.

For gestures controlling music, a question was raised about the possibility to skip to a specific track instantly, or skip several tracks at once, as well as the possibility to fast forward. Using physical buttons one can quite fast skip multiple tracks by repeatedly pressing a button. A swiping gesture does require the users to move their hand back and forth left and right, which would be much slower and also tiring for the users. Hence, there should be a modification to the gesture that allowed the users to do the gesture once and then hold, or similar. Swiping to the left and then still holding the hand on the screen could be used to either continue to skip tracks, or fast forward, as an example of such a modification. Also, for music and media, there should be a part of the screen that always showed what track the users are listening to, which then would also provide feedback when skipping tracks.

One of the main discussions was also whether or not it was needed to make a distinction between home and close as well as all applications and home. With a smartphone, one is encouraged to download and try a lot of new applications, and there could thus be a reason for sorting out the most important ones to allow the not as frequently used applications to still be installed on the phone. However, in a car environment this behaviour would perhaps not be as prominent, but a better approach would be to keep it simpler and remove the entire excise to make the system easier to learn. If there should be a distinction between *home* and *close*, which there has to be since one should be able to multitask (use several applications simultaneously), then the difference between the two gestures should be much clearer.

A similar approach to the one used in iOS and Android would be preferable. Their approach is to assume that the users most often would only like to go *home* and thus makes this the default behaviour. To completely close an application one has to open up a view for active applications and from there, close it. If one still should be able to close an application with a gesture, then the animation must also differ a lot from the home animation. In Windows

Phone the application window shrinks and the user could then throw it away, making it obvious that the application no longer is active. The quit gesture must similarly visualise that the application not only shrinks down or is put away by the user, but that it gets destroyed or thrown away, or a similar metaphorical meaning.

Lastly, which to some extent already has been discussed, the evaluators wanted to stress the importance of visual hinting for what and how the users can interact, together with multimodal feedback and acknowledgement of each interaction with the system. The group found most gestures rather intuitive or learnable and believed that the underlying pattern for how many to use, would be understood by most people, as long as proper feedback is given.

4.11.3 Conclusion – Expert evaluation

After the expert evaluations, it seemed as the Designers' concept was the more promising one that also would be easier to learn by most users. This concept had an underlying pattern for the number of fingers mapped to music, climate, or system specific actions. Using this pattern increases system's coherency and helps provides an inner logic to remember. By knowing the underlying pattern, one may divide the learning process into steps: first the pattern for fingers and then the gesture to perform. All of the evaluators considered learning the pattern easy and the gestures could be learned incrementally. The Users' concept did also try to achieve this structure, but with some gestures breaking the pattern, it was instead confusing and the Designers' concept was thus easier to learn and use.

However, without proper feedback many users would still look at the screen and thus beat the purpose of both concepts. Both evaluating groups have commented on this and one could thus also conclude that the feedback, indicating that the users have succeeded with the intended gesture, was as important as the mapping of suitable gestures.

After the expert evaluations, only the Designers' concept continued with further user testing, since it was considered the most promising one. The concept was named GABI (Gesture Action Based Infotainment) and together with a few small changes, the prototype was ready for user tests in a driving context, which will be described in the next chapter.

Figure 16 Placement of the prototype in the center stack of the car

4.12 Evaluation of final prototype

After the development process of the two prototypes, with several iterations, user tests, and expert evaluation, the Designers' concept was thought of as most promising. This was mainly because the Users' concept lacked a strong inner logic and coherency. With short time remaining, it was only possible to evaluate one concept. Based on previous tests and evaluations, the Designers' concept was seemingly more intuitive which was why the Designers' was chosen for further evaluating and development. This chapter describes how a prototype using the Designers' concept was evaluated using a slightly modified version of NASA-TLX to measure the experienced workload while driving and interacting with the system. The prototype was compared to a baseline value, which represented the participants experienced workload while driving without any interactions with an infotainment system. Also, along with the driving tests, semi-structured interviews were conducted to get initial user feedback and opinions about the system. For complete information and results from the tests, see Appendix VIII.

There were seven participants, six men and one woman, aged between 25 and 59 years old, having mixed driving experience. The prototype was placed in the center stack of the car, see Figure 16. The test consisted of two parts: The first part tested the system's learnability, and the second part tested how the users could manage the system while driving. This second part was evaluated using a modified version NASA-TLX for measuring the users' experienced workload, and semi-structured interviews to gather opinions and comments about the system. For an overview of the evaluation, see Figure 17.

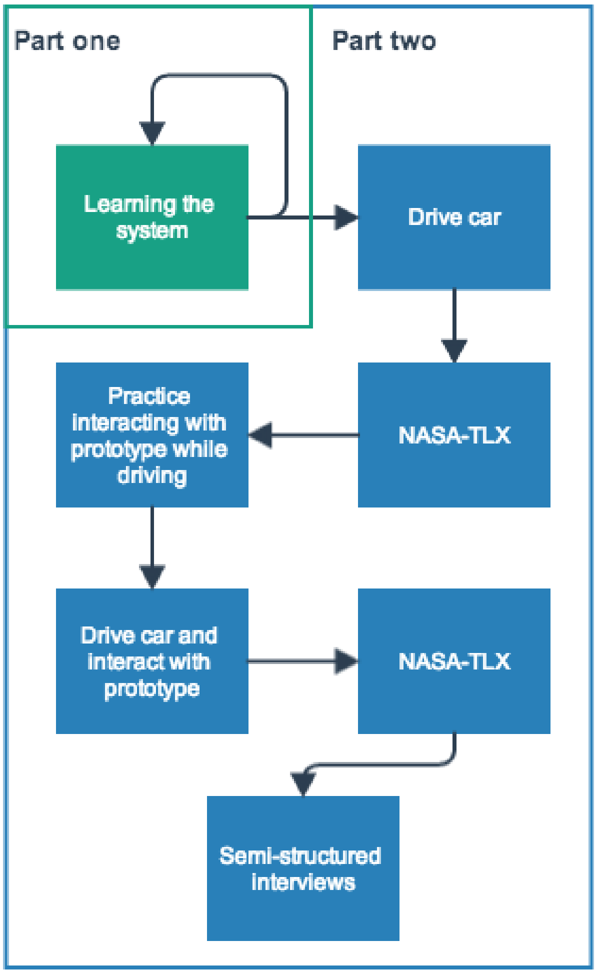

Figure 17 Overview of the evaluation of final prototype

4.12.1 Learning the system

The general strategy when measuring the system's learnability was to iterate through all gestures in the concept and count the number of iterations needed to remember all gestures. The test leader started the test by explaining how the system works and which gesture mapped to which action. The participant was then asked to perform actions from a predefined use scenario with instructions to set a comfortable volume level, set temperature on two thirds (at this point the prototype did not have discrete values, but only a scale from min to max), or opening up the favourite application. The full use scenario can be found in Appendix VIII. The gestures which the participants did not remember were explained and asked for again in the next iteration. When all actions were completed successfully the learning was considered complete, and the number of iterations was noted.

4.12.2 User experience

This part was divided into two sub-parts, consisting of workload tests from two situations and interviews.

The first part of the workload tests was to let the participant drive the car normally and try out the predefined test route of approximately one kilometre. The participants then got to drive the route again and interact with the prototype, to practice while driving. As a last step, the participants got to drive the route a third time, the actual performance test. The participants then got to carry out the same use scenario as when learning the system earlier. To document the behaviour when interacting with the system, all the participants were filmed from two angles (front and rear), for potential (future) analysis.

After each of the driving sessions the participants got to evaluate the workload, using the modified NASA-TLX. To have a value to compare with the participants did one pre-evaluation: the first was to evaluate the task of driving and following instructions for the route, the second test evaluated the same thing in combination with using the gesture prototype which had earlier been learned. The user got to grade the six factors on a scale from 1 to 6 and weigh all factors against each other.

In addition to this, the tests were followed by unstructured interviews, asking the participants to reflect on, and give feedback about, the prototype.

4.12.3 Results

Below are the results from the evaluation of the prototype. The results are presented in two subchapters, learning the system and user experience.

Learning the system

From the first part where the learnability was evaluated the results show that the system can be learnt with relatively few iterations. None of the participants could perform all the gestures on the first iteration but four of the seven participants carried out all the gestures correctly on the second iteration. The remaining participants used three, four and eight iterations respectively to successfully perform the gestures.

The tests also show that some gestures in the concept were more difficult to remember than others. These (harder) gestures all included four fingers; switch between applications (four finger swipe left or right), go to “home” (four finger long press), open view with all applications (four finger swipe up) and favourite application (four finger double-tap).

User experience

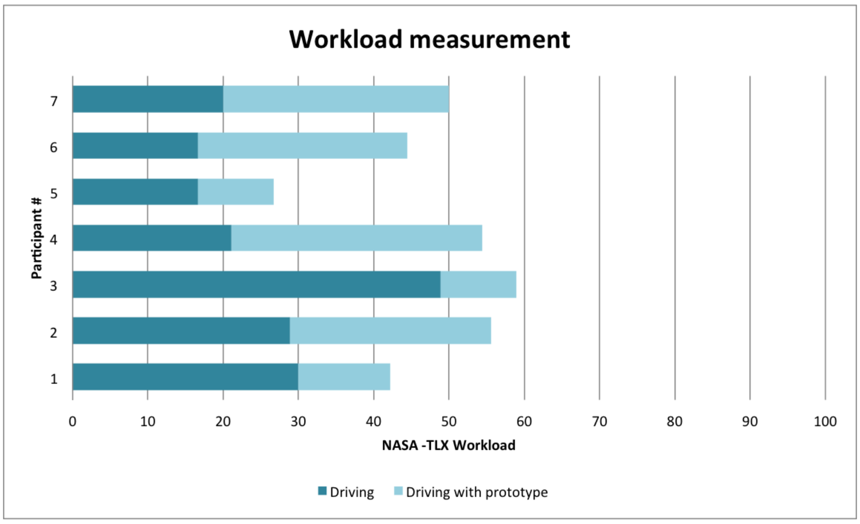

Figure 18 The experienced workload during the driving tests shown per participant

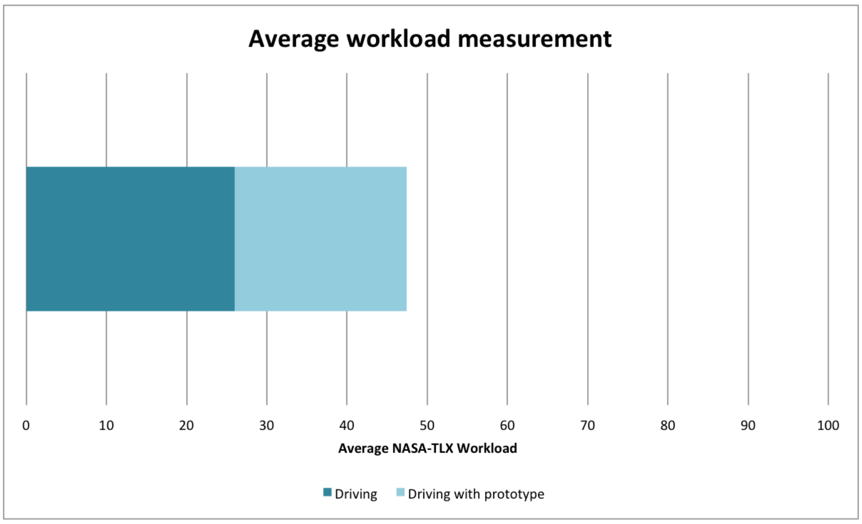

Figure 19 The average experienced workload during the driving tests

To measure the workload the participants got to answer a NASA-TLX survey. The results of the experienced workload are shown per participant in Figure 18 and average in Figure 19. The seven participants estimated the workload when solely driving the car on average to 26 of 100. When adding the interaction with the prototype to the evaluation the number was estimated to 47 of 100.

By factorising the average workload value, it becomes clear which factors contributed most to this relatively large increase. In Figure 20 it can clearly be seen that many factors experienced workload have doubled when driving with the prototype. The two that contributed most to the workload score was, in both driving contexts, mental workload and performance, which values have both doubled when driving with the prototype. Also frustration and temporality have increased. However, since having small contribution to the total workload score in the first driving context, their effect when increasing is not as noticeable. The participants did also give effort a higher score when driving with the prototype. What also should be noticed is that the participants physical workload did not contribute to the total as much as when driving without the prototype.

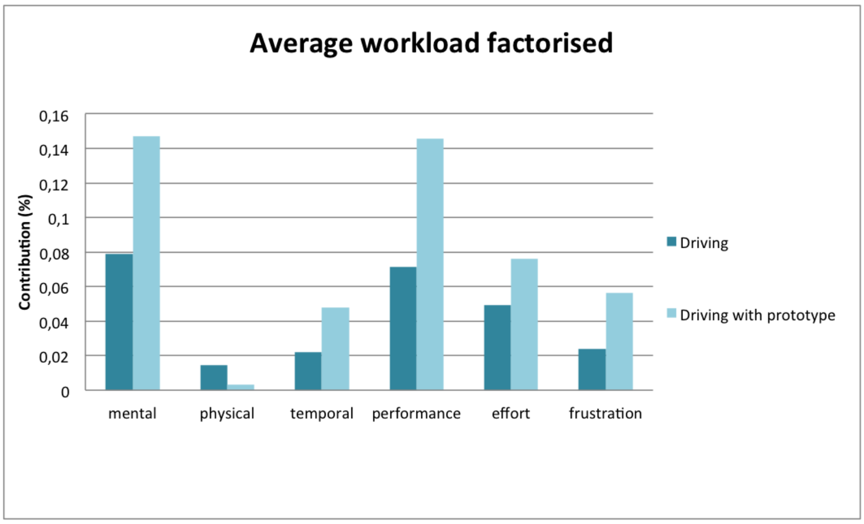

Figure 20 The average workload factorised

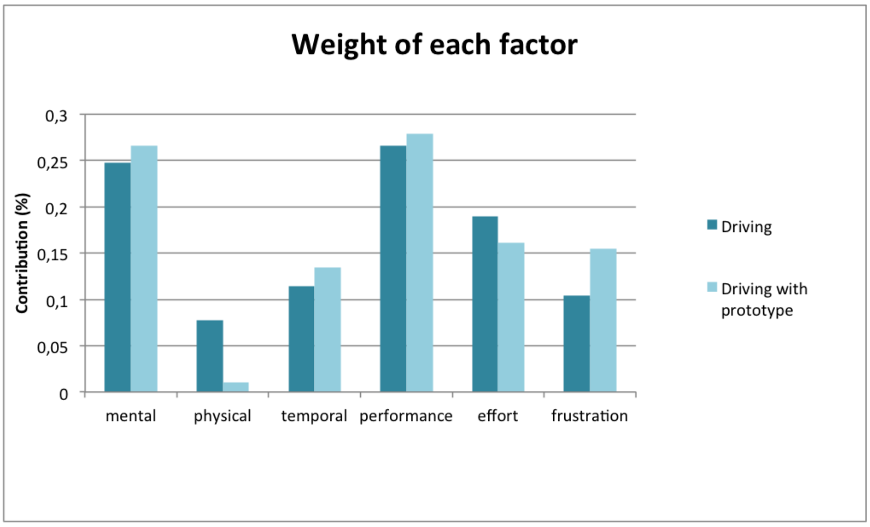

Figure 21 The weight of each factor

What also can be extracted from this test, was what factors the participants considered contribute more to the total workload, see Figure 21. When the participants drove the car they considered their own performance to be main contributor to the workload, this in both driving contexts. The performance was closely followed by the mental workload, again in both driving contexts. The remaining factors are ordered as follows when only driving: effort, temporal, frustration, and physical. When driving with the prototype the order is now: effort, frustration, temporal, and physical. see Figure 22.

It was prominent from the interviews that the general experience of learning and using the prototype while driving the car was positive, even though many of the participants would like more time to practice in order to remember all the gestures. It was something that all participants would like to use in their cars. The advantages the participants mentioned included the benefit of having a full area to interact with instead of having to find and hit the right physical button. The participants also agreed that with more practice such a system would decrease driver distraction compared to interacting with other systems. Another benefit of having gestures controlling the infotainment system is that these gestures could be used cross platform, enabling the user to learn only one set of gestures and their mappings. The fact that the gestures are all software implemented makes the system more flexible compared to systems using only physical buttons.

On the other hand, systems relying solely on touch interfaces have to provide other means of feedback to the users, due to the lack of tactility, a concern which was also raised during the interviews. The participants often commented on the need of better feedback to avoid looking at the screen. Some of the participants also highlighted the learning curve of the system and that they wanted to have more practice in order to use the system more efficiently.

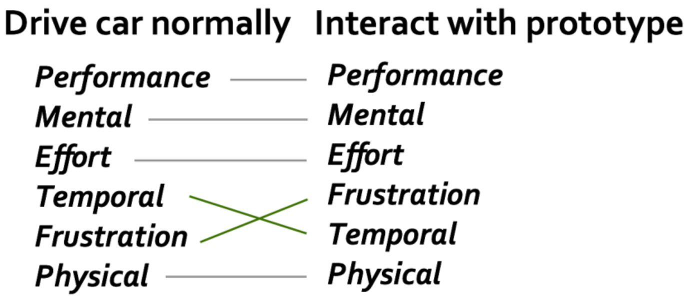

Figure 22 Contributors to the total workload, ordered top-down with the most contributing factor first

Considering the gestures of the system, the participants thought some of the gestures to be complex and hard to distinguish between. This mainly concerned the four-finger gestures. While most of the gestures felt intuitive and easy to remember, the mapping of the four-finger gestures felt somewhat strange. Another gesture that caused confusion among some of the participants was the direction of the swipe when skipping to next (swipe from right to left) or previous song (swipe from left to right). One approach can be compared to flipping pages in a book, or as seen in many music applications where the users can scroll through album covers by swiping left or right. The second approach can be thought of as drawing an arrow in the desired direction (the prototype is implemented with the "flipping-pages"-metaphor).

4.12.4 Analysis

The driving tests aimed to arrange an environment as close as possible to a real driving context. Being able to actually test the prototype in a moving vehicle was crucial to be able to retrieve relevant feedback from users who used the system while driving and could image how it would work when built as a native system. To get more precise measurement of the distraction, for example *eyes-off road time* or *lane deviation*, a driving simulator test might have been more appropriate to use. However, the test aimed to get an initial acceptance and an indication of the system's performance.

The results from the learnability test indicate that the gestures seemed fairly easy to remember and the users often needed few iterations to complete all given tasks. However, during the test it became obvious that even though the participants completed the learnability test with ease, some gestures were not remembered while driving. During the time passed between doing the learnability test and the driving test, most participants had already forgotten some of the gestures and had to be reminded. This might be due to the restricted resources in the human working memory, which is said to be capable of managing 7±2 objects simultaneously (Ware, 2004). Albeit these limits, what the concept aims to achieve is rather to encourage the users to evolve into expert users by learning a set, or chunk, of gestures at a time, than to force the user to know all gestures at once. The user can thus practice to instead know, or remember, the gestures. Hence, we would argue that users would benefit from having more time to get acquainted with the system to be able to compare its performance with existing solutions.

The short time to practice was something we were aware might cause problems, which was why we chose not to measure any parameter of learnability during the driving tests. In addition to this the learnability has not been our priority per se, intuitiveness has been of higher priority, but we wanted to get an indication of the learnability as well. It should be noted though, that this type of test might not be enough to conclude that the concept actually was easy to learn, but gave an indication of the learnability. It would have been preferable to let the participants use the system for a longer time period to avoid the risk of learning the test sequence instead of the gestures in the concept.

Since intuitiveness was prioritised when developing the concept, it would have been interesting to evaluate this. This was something we did not have resources to evaluate and we considered the learnability to be more important to evaluate. The reasoning behind this was that the users were not mainly going to learn the system by exploring, but rather being given a guide when using it for the first time. It was the potential effect of this guide step we wanted to evaluate, and if the system was rather intuitive, the learnability of the system would increase.

Concerning the gestures if the system. It was not surprising that users had a hard time using the four-finger gestures, since the problem had already been highlighted during previous tests. The four-finger gestures are physically hard to perform, since the users have to keep all fingers on the screen while completing the gesture. This seems to be especially hard with the little finger. Another reason why four-finger gestures are more complex could be, as early iterations of the gesture mapping indicated, that no intuitive gestures were found, which made it harder for the participants to remember these gestures-action mappings.

The results of the workload tests indicated that the experienced workload increased when using the gesture prototype while driving. It would have been interesting to compare this prototype with similar systems to get a better understanding of whether the workload was higher or lower than systems as advanced as GABI. Comparing it with normal driving gave an indication of how the system was compared to normal driving. If it was possible to keep the workload close to the baseline, of normal driving, it would be a good indication that the system was minimising the distraction when using the infotainment system. However, there could be many reasons for the increase of workload and we have identified some which we think were the main contributors to the relatively big increase (from 26 to 47 of 100).

- The first reason was the lack of practice the users had before using the system. If the users had deeper knowledge of the system and had been using it for some time, the total workload would probably decrease. Not being forced to think about the gestures would probably also result in less frustration when not remembering or using the wrong gesture.
- The second reason was the driving route. The selected route contained relatively narrow roads, pedestrians, bicycles, crossings, etc. All of these things appear in a normal driving situation, so this was no exceptionally hard route, but in combination with testing the prototype and the (putative) willingness to perform well, it all added up to a higher workload.
- The third reason was the driving task and the test case. When driving normally you would maybe even not use all functionality that was tested. Even if you did, you would probably use it under less extreme conditions. This relatively short route, that the participants were following, made the intensity of the task higher than normal and was thus more demanding than in a real use case.
- The fourth reason we identified was the fact that the two different driving tasks are hard to compare. There is a big difference when being able to focus on the driving task alone, compared to adding an extra task. Even though it was good to have a value to compare with, the baseline, it might have good to also to have two more similar tasks to do a more fair comparison of the workload. However, the baseline still gives a value to aim for, since the ambition was to reduce the distraction from the infotainment system.

Another concern about the NASA-TLX methods was that some of the factors were perhaps somewhat ambiguous to understand. Albeit trying to explain the factor's definitions, there might still have been misconceptions. Considered especially hard were the temporal and the effort factors which we think are the factors which were most often misinterpreted. In addition, the participants did two evaluations using NASA-TLX and it is hard to tell if they had different understanding of the factors when doing the two evaluations.

However, the increased experienced workload should not be neglected, since it will affect the drivers' performance. As a comment to this, it should be repeated that the participants stated that they considered this system to be a way of decreasing visual distraction, but they also highlighted the importance of practice and using the system to learn all the gestures properly. As mentioned, it would be interesting to perform similar user studies on systems with equally functionality.

Letting users practice with the system, the mental workload would probably decrease along with the performance factor. Since these are the two main contributors to the experienced workload, a decrease in these factors would have a big impact of the total workload score. Having more experience using the system, would probably also reduce both users' frustration- and effort. These are the two following factors which are important contributors to the total workload score.

The users got to grade the workload on a 6 point scale, instead of the original 20 point scale. The motivation for this change was to make it easier for the participants to distinguish between the different values. Another motivation for the change of scale was that the participants were now forced to make a more distinct selection of which side of the middle the answer would be. The drawback with a change was that the granularity was less making the answers more ambiguous, this means that the lowest workload that a user could experience was approximately 17. Another drawback could be that it is harder to compare the results with results from other workload tests when not using the same scale for rating. The learning from this study was that it would probably have been wiser to keep the original scale, to be able to compare the workload with other workload studies.

From these tests and the discussion we concluded that the testing indicated that the system seemed fairly easy to understand and can be learnt with relatively few iterations. Given more time to practice would be beneficial for the users and would probably reduce their mental workload and improve their performance. We could also conclude that the participants of the test generally had a positive attitude after using the system in a driving context and that they all could imagine themselves using such a system in their own car, at least some of the functionality.

5 FINAL RESULT

5.1 Interactive prototype

The GABI prototype was developed as an iOS application, using the development environment Xcode[11], running on an iPad (both 2:nd and 3:rd generation). The main screen was a "dashboard" that showed a suggested layout for a home screen, a grid layout for application icons, see Figure 23. In the prototype these suggested applications were music, messages, phone, audio books, car, and settings. The applications did not have any actual functionality in them, except for the music application and the telephone application which presented a scenario simulating an incoming phone call that the user should act upon. The users could open up any of the six applications and browse through them as intended in an actual system.

The prototype does not provide any traditional interface components for browsing the system, but relies on a set of universal gestures that can control specific features and can be performed from anywhere. The gestures controlling these features and actions are the following:

Figure 23 The dashboard of GABI (Icons made by Stephen JB Thomas, from The Noun Project, Creative Commons Attribution)

Two fingers – Media

Gestures using two fingers all control media features: volume, play/pause, next/previous.

Three fingers – Climate

Three finger gestures control fans (speed) and temperature.

Four fingers – System / applications

Four finger gestures are all paired to features on a system level and are used to switch between and close applications, show all installed applications and go to a predetermined favourite application.

Figure 24 explains the gesture-action mapping and the concept of GABI in more details.

[11] https://developer.apple.com/xcode/

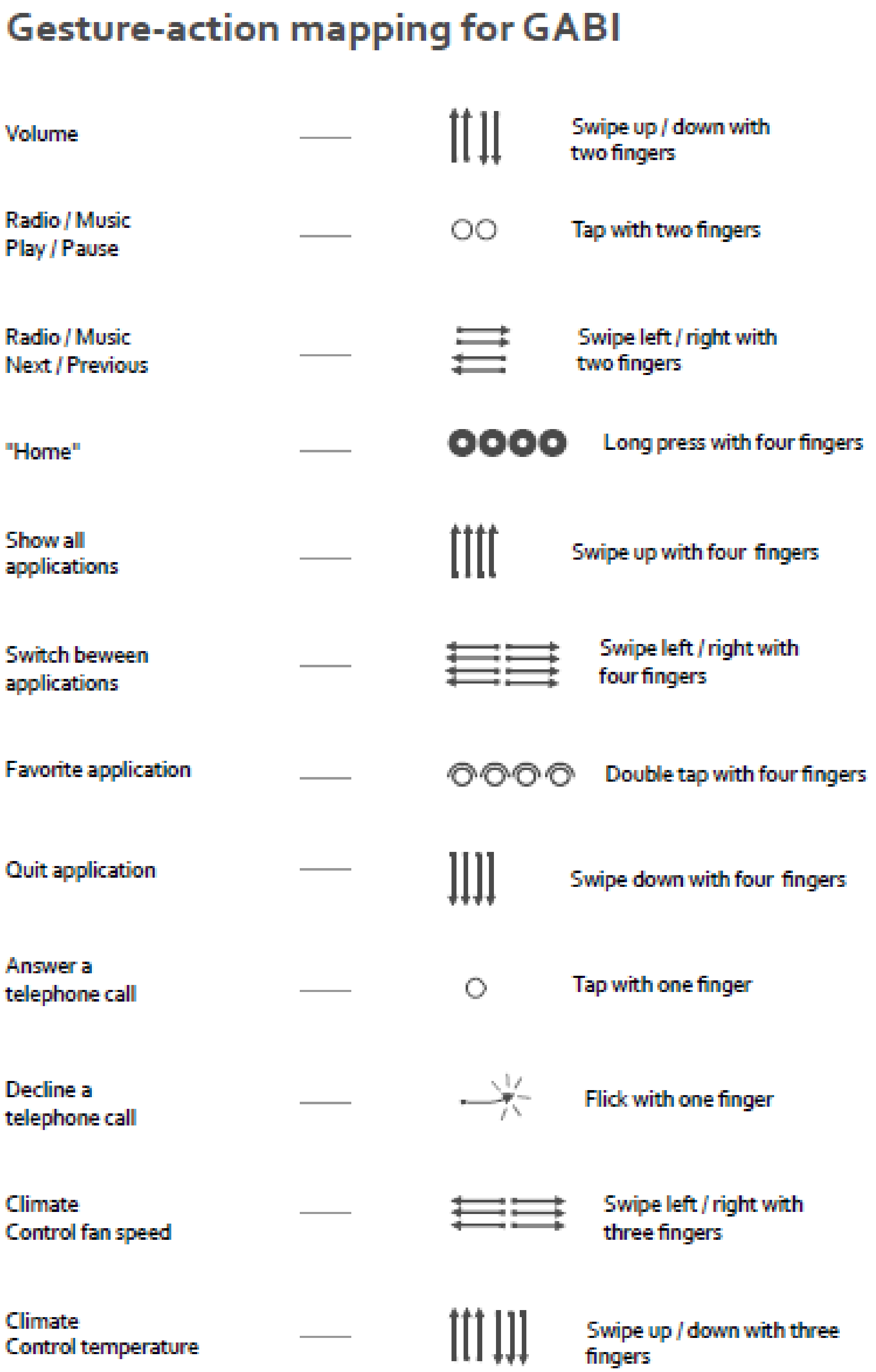

Figure 24 Gesture-action mapping for the GABI prototype

5.2 Design guidelines

During the process of this thesis we have gathered information through literature research, user tests, and evaluations of the final prototype. Combining these stages resulted in a set of guidelines for how to design gestural interfaces. These guidelines can advantageously be used as a complement to already existing laws, restrictions and guidelines, and aims to improve the user experience but still emphasizes the importance of user distraction and off road-glance durations. Our additions to the already existing guidelines are the following:

5.2.1 Whenever possible, use already known conventions

Today, about fifty percent of the Swedish population owns a smartphone (Google, 2012) and the number is increasing. With the new trend of smartphones and tablets, people are getting more used to touchscreens and new applications are experimenting with new gestures and new ways of interacting. These gadgets are all great resources for teaching users new gestures and instead of trying to invent gestures in an environment where experimental gestures potentially could cause accidents, it is better to make use of gestures that users already know. An example in the GABI prototype of one such approach is the gesture for switching between applications. Similar to how iOS uses this gesture for switching between recently used applications by swiping with four fingers left or right. This gesture is implemented as an advanced feature in the Apple iPad and already known to some users, see Figure 25.

Figure 25 Left / right four finger swipe comparison. Left picture shows iOS, right picture shows GABI

5.2.2 Do not just invent new gestures - ask the users first

When designing a gestural interface, the designers might be tempted to use their own judgment and think that most users would agree with their own preferences. However, what could be concluded from user tests during this thesis is that people think differently, especially if the user has no previous experience from a similar task. Whenever possible, one should try to follow already set conventions. If no such convention exists, a good approach is to ask the intended user group about their opinion and try to follow the mental model of the majority.

5.2.3 Make the touch area big enough

Reading the design guidelines from iOS (Developer.apple.com, n.d.), Android (Developer.android.com, n.d.), and Windows Phone (Msdn.microsoft.com, 2013), the recommended minimum touch target should be 40-48pt, which means that the physical touch area should be approximately 1x1 cm. Saffer (2008) suggests that this area should be 150% enlarged to allow most people to be able to interact with good precision. In a driving context, the precision is worse than using a smartphone or tablet, and it is even more important that the precision is accurate. Hence, we recommend the size of the touch target to be at least 1.5x1.5 cm, but preferably even 2x2 cm, see Figure 26. However, these recommended sizes have not been performance tested and should thus not be referenced to as universal truths.

Figure 26 GABI's large icons on the dashboard (Icons made by Stephen JB Thomas and Iconathon, from The Noun Project, Creative Commons Attribution)

5.2.4 Use patterns

When designing gestural interfaces one should try to group features, similar to how it is encouraged to group buttons and graphical components in GUI design (Cooper et. al., 2007). This will help when later deciding what gesture should be used to control a certain feature or action in the system. During the iterations of our gesture-mapping, the expert evaluations, and in the final user tests, we have observed and received feedback about it being easier to remember gestures when knowing that a certain number of fingers were mapped to certain categories of features in the vehicle. The pattern used in GABI is the following: two fingers controls music, three fingers controls climate, and four fingers work on an application/system level. These patterns could be thought of as chunks and helps the user to manage more gestures without increasing the cognitive workload (Ware, 2004).

Remember that gestures, as far as possible, should have the same effect in all situations. Using the same gesture with different purposes, breaks the users' mental model and with it, the user experience.

5.2.5 Often used features should have simpler gestures

Together with patterns, one should also try to consider how frequently used certain features or actions will be. The more often a feature will be used, the simpler and faster the gesture should be. Less frequently used features would thus not need to be performed as fast and could make use of a more complex gesture if necessary. However, in a driving context one has to consider whether the feature is time critical or not and whether it is performed while driving or not. Naturally, a time critical action performed while driving, should be controlled with a quick and easy gesture.

5.2.6 Make a clear distinction between gestures and be flexible

After observing numerous people interacting, both with paper prototypes, drawing applications, and the GABI prototype, we can conclude that people have many different ways for achieving the same thing. Hence, the system needs to be flexible and forgiving when recognizing gestures. An example, which sometimes causes a problem in the GABI prototype, is that it is required by the user to swipe with a certain velocity before the gesture is detected. This was most noticeable with four finger swipes, since the user has to keep all fingers on the screen while swiping, which proved to be more difficult than expected, see Figure 27.

Figure 27 Interacting with GABI using four fingers

5.2.7 Offer an easy way to undo

Even with the best design possible, chances are that a user will make mistakes and change something that was not intended. Thus, one should always provide an easy way to undo or restore to previous state without too much effort (Cooper, 2007; Saffer. 2008). An example of this that occurred while user testing the GABI prototype was that some users by mistake change the volume when the intended action was to change climate settings, see Figure 28. However, since the user easily could turn the volume back by simple swiping up or down with two fingers, there was no problem.

5.2.8 Do not use too many gestures

One theory of the human working memory is that it is only capable of managing 7±2 objects simultaneously (Ware, 2004). Therefore, even though one might be tempted to add as many gestures as possible, it is recommended not to make use of too many. Only the most frequently used most important features should be mapped to a gesture.

Figure 28 Changing climate settings in GABI (Icons from The Noun Project, Creative Commons Attribution)

5.2.9 Support multiple levels of expertise by providing multiple alternatives

In traditional mouse and keyboard computer systems, it is common to offer multiple alternatives to achieve the same end result. An application menu guides the user through the hierarchical tree structure step by step, which is why it typically is used by beginners. However, quite often the most frequently used actions and features can be performed with a keyboard shortcut. Each shortcut is often visible in the menu and the user can thus be reminded while using the menu until he or she feels certain of the shortcut. In the GABI prototype, the user can choose to either enter the music application and from there play, pause, or skip tracks or control the mentioned actions by using gestures.

5.2.10 Make use of different levels of complexity and allow the user to develop into an advanced user

Not only can there be alternative solutions such as visual components and gestures. One might also provide the user with gestures with different levels of complexity. This would allow the user to learn a few simple gestures at first, and when feeling comfortable using these, they are able to advance and add more sophisticated gestures.

5.2.11 Allow customisation

Throughout the design- and development process of the thesis, one question that were asked multiple times was whether skipping to the next track should be mapped to a left or right swipe. Multiple times the person answering this question intuitively says one thing, but when interacting with the prototype does the opposite. Hence, some gestures, that have the possibility of doing so without breaking the overall experience, should have the option to be reverse or changed according to the users' own preferences.

6 DISCUSSION

This chapter will discuss relevant topics about the process and the final results and the evaluation of the prototype. It will also include discussions about free-form gestures and future work.

6.1 Process Discussion

Throughout this thesis there has been a strong emphasis and focus on keeping a HCD process. Already from start of the project we considered this to be extremely important. To be able to develop something which has been refined from the users' opinions seems like a rare opportunity within the industry and has both been an experience and interesting for us. Even though the HCD process could seem like time consuming work it has also yielded results which we probably would not have reached otherwise. Having done the user studies made us consider each action more thoroughly and forced us to realize that things we initially thought of as obvious, others had a completely different conception of. Having our studies and user tests to back up each decision was important when motivating the gestures in GABI.

We have learned the importance of setting clear goals and to delimit the project properly to know what results to expect. Even though we considered the initial goals and delimitations as done properly it was not until the re-focusing of the project that we fully understood where this project was going to end up. Before re-focusing the project, we had a hard time figuring out what was considered useful and important information or research, which resulted in us having a wide perspective of the topic, discussing almost everything from size and position of the physical touchscreen, what colours and font sizes that were recommended, and strategies for reducing the disturbance from a dirty screen. There were also discussions about how one could develop a framework for third-party developers and how much freedom a developer should be allowed when designing the interface of his or her application. After narrowing the scope and making the decision to focus only on gestures and how these should be designed and supported, there was much more of a clear path to follow and we could make a structured plan of how the work would proceed in order to reach our goal. Having clear goals from the start of the project might have helped us to avoid performing methods of which the results cannot be used in the final result. On the other hand, it might have been good for the project that we actually experienced the first part, where we had a broad scope, for us to be able to narrow it properly. Clear goals do not guarantee that there will be no mistakes, but it would hopefully help planning relevant methods and tests.

What we have learnt from designing our own work process is that each activity and contact with users and evaluators needs to be well planned and thought through to generate useful results and feedback. Even though some of the used methods were hard to extract, for the project, relevant information, we have still learned from them. Apart from how to use and conduct the different methods we have also learnt the importance of designing user tests down to every last detail. The tests have to be planned in details concerning aspect like time issues, expected results, format of results, participants, etc. and the participants must get clear directives for what they are expected to deliver.

Concerning participants in each user test and workshop, we have strived to keep a mix of people having different ages and different backgrounds. However, it has not been easy to get people without any connection to participate and many tests has thus been done with a majority of high educated people, whom might be more accustomed to technology than the average. One could argue that the mix of people used in our tests is be a proper representation of the intended user group and would thus be valid for that reason. However, this is not something we can prove, since the aim of the thesis was to elicit guidelines for developing in-vehicle systems for the general public.

During the workshop an interesting topic was brought up, namely whether it was suitable to use touch interaction in vehicles at all. There were some different opinions on the topic but it seemed like the general idea was that the participants were negative about the evolution towards touchscreens in cars. There can be several reasons for this. One can be that most of the participants had never tested such a system and could only imagine how it would be resulting in negative approach to touchscreens because of lack of the physical buttons and their tactile feedback. However, the purpose with this thesis was to investigate how to reduce visual distraction and thus off-road glances. By implementing universal gestures which were not reliant of a specific area on the screen or that the user is in a specific application, we believed that the user could find the touch area, which was much larger than a single button, without looking away from the road. The lack of tactility was obvious, but could possibly be solved with auditory- and haptic feedback, such as vibrations in for example the chair or the screen. However, this was only our belief and not something we can prove until such features have been added and further tests have been conducted.

6.2 Result Discussion

The outcome of this project has been a set of gestures mapped to actions which can be performed on an infotainment system in a vehicle. During the development of these gestures the aim has always been to make them as user friendly and intuitive as possible, as well as effective enough not to distract the drivers more than necessary. The final prototype is based on the results from the preceding user studies of mapping gestures to actions and actions to gestures. We found that it is hard to develop a coherent concept, without involving more demanding gestures than using one or two fingers. However, the solution which GABI presents solves the problem that some gestures have similar intuitive mapping by making use of an underlying pattern that determines what number of fingers to use depending on what feature one wishes to control. The pattern also helps the users to choose level of complexity of the gestures to perform, and most users will be able to control the most frequently used features with gestures.

The pattern uses results from user studies and a survey, which indicated that music seemed most important for the users to have easy access to, climate second most important, and other controls, which were not included in our prototype, were rated as less important. The prototype is thus using two fingers (easy to perform) for controlling music, three fingers (intermediate complexity) controlling climate, and more demanding gestures using four fingers (harder to perform) for controlling system specific actions.

After a number of iterations of gesture mapping, user tests and expert evaluations, we concluded that most people seems the embrace the concept of using gestures to control the system's most, based on results from the survey, important features. The simplest gestures for controlling music were easy to comprehend and perform by most people trying the system. However it became obvious that feedback is necessary for almost every interaction a user does. Most evident was the lack of complementary feedback when changing temperature. Since changing it would not result in an immediate change of temperature inside the vehicle, it is necessary to acknowledge the interaction for the drivers to know that their gesture had an effect. Also, what could be concluded from our last user tests in a driving context, using more than three fingers seems significantly more complex and should thus not be used for any critical features or actions, since not all users will be able to use them. This ties back to the theory chapter about choosing gestures.

Since the gestures are not limited to specific zones, the gestures can be made wherever on the screen the users find it comfortable. All gestures can also be performed quickly and we believe they would not require much effort after getting used to the system, which would allow the drivers to achieve complex navigation without distraction. In the prototype, a certain velocity is required to "activate" certain controls. This is merely an implementation issue and not intended for an en product. However, one could argue whether this would reduce misreadings from unintentional touches. The gestures can be made both subtle and as gross movements, but none is required. Hence, does the system not force users into any exhausting positions. However, one might argue about the placement of the touch area itself. Although the thesis did not include research about the screen's placement, or whether the screen should be used as a touch surface at all, this is of utter importance to an end product. If we were to speculate about this, one possible solution would be to place a touchpad close to the driver's armrest and let the driver perform the gestures on the touchpad instead of the screen.

Even though most people quickly understood the Designers' concept, it was still obvious that most people needed more time to learn the system. Also the user tests done were rather extreme, since the users were asked to perform a gesture about every hundred meter. However, when asked, everyone could tell how many fingers they intended to use to achieve what was being asked of them. Most difficult, as mentioned earlier, were the four finger gestures. After observing the participants in a driving context we could conclude that these gestures do not really have a natural mapping to the action and could thus be used to achieve any of the actions, especially the gesture for *home, quit,* and *favourite application.*

The favourite application gesture seemed to be useful but most participants had not encountered this concept before and were thus a little confused about it, but could find it useful. During the expert evaluation it was discussed that the manufacturer could use this gesture for an application or a view that they find important. It could be a gesture for entering a settings panel within each application or similar. We would however argue that it would be a useful feature that one could allow the users themselves to map to any application they wish to.

The GABI system utilises some complex gestures which requires more practice to remember and perform. However, comparing this to having specific designated zones for controlling different functions, the GABI system having universal gestures enables the user to interact without visual distraction. Having zones to interact with would increase the need of looking at the screen while interacting to verify that the intended zone is used. A concept using zones is more comparable with having physical buttons, but with the disadvantage that the touchscreen lacks the tactility of the physical buttons.

While prototyping the GABI system, the interface and visual design has not been our focus. Hence, not much effort was put into making visual details perfect. The only real design decision made was inspired by the Modern UI design language mentioned in the chapter about gestural interfaces (2.2). The simple design with large touch areas and minimalistic icons help us achieving an uncluttered dashboard, which looks professional and thus gives the impression of being a real system. Hence, the users in each test could imagine and understand the situation better.

The iPad's performance was more than enough to achieve a feeling of immediate response. However, since a few gestures were quite similar, a certain threshold was implemented to avoid interference and incorrectly triggered actions. This did not seem to be a major problem during the final evaluation in a driving context, even though a few users were not immediately compensating for this threshold. However, we believe that one would get accustomed to this after using the system for a while.

The components are all big and easy to interact with and no extreme gestures are used, even though the four finger gestures might be too complex for certain users, like elderly. However, none of the gestures force the users' into strained positions and all of our participants during the final evaluation managed to perform each gesture without commenting about such problems. Instead the problem was implementation wise, how the prototype sometimes did not recognise four touch points, even though the evaluator clearly had four fingers on the screen.

6.3 Touch vs. Free-form gestures

Initially this thesis was supposed to concern free-form gestures as well. Despite all research and testing have been done on touchscreens, we have always tried to be conscious and consider how our touchscreen gestures could be adapted to a 3D-space. However, we also believe that the best way to approach designing gestural interfaces in a driving context is to first decide on what gestures are suitable or not as touch gestures and afterwards use these and develop the already known gestures into free-form. In a vehicle one also sits fairly close the panels, which could cause problems when people inside the vehicle moves and accidentally triggers gestures, which still is discussed as a problem with our touchscreen solution. Hence, our approach was to initially focus on touchscreens and let future work build upon our research to develop free-form gestures as well.

6.4 Future Work

Many of the topics which have been out of scope for this thesis are relevant to continue to investigate. First of all, we have excluded most feedback in the prototype, which of course is something that a complete system would need and should be further evaluated and tested. The current feedback in the prototype has not been prioritised when developing and needs to be refined in the future. Future work would also include incorporating better feedback using various modalities. The project did neither consider the prototype's look and feel, which gesture hinting would be a major part of. Much of future work would consider the complete use scenario. Gesture hinting is required for the users to know what gestures are available, what gestures to use is one part, researched in this thesis, and proper feedback to acknowledge each of the users' interactions and appear as trustworthy as it is.

The continuation of this project would also include how to educate the users to learn the system and continue from only using buttons to utilise GABI. Yet again is gesture hinting important, but one also needs to consider wizards, help menus, and other support systems that would be of advantage to the users.

Even though we have performed initial user studies concerning the use of the system and how the users felt when using the prototype, the system would need more thorough user testing. And example of a relevant test perform, is to compare GABI with similar systems, both similar systems that utilises touchscreens and systems using only physical buttons. Possible parameters to evaluate are both workload, using for example NASA-TLX, or time to complete different tasks. Naturally, it would also be interesting to measure off-road glances and duration of these to get indications of a gesture-based system's performance.

To further utilise the findings of the user studies in this thesis, future work would include investigating free form gestures. This would include investigating if the interaction is similar to touch gestures, if it is possible to transfer touch gestures to free form gestures etc.

7 CONCLUSION

This project's aim has been to use gestural interfaces to minimise visual distraction when using touch-base in-vehicle infotainment system. This is especially important because of the lack of tactile feedback from touchscreen, which may result in users looking at the screen for feedback.

The thesis's has followed a human-centered approach and the process was designed accordingly. GABI (Gesture Action Based Infotainment) was developed, with universal gestures controlling specific features, for example music, from anywhere in the system. These gestures were elicited from extensive user studies and multiple iterations of refinement to provide a coherent inner logic that users can learn and remember. The gesture-action mappings in the systems are as follows:

Telephone - One finger

- Answer a telephone call: *Tap with one finger*
- Decline a telephone call: *Flick with one finger*

Music - Two fingers

- Volume: *Swipe up / down with two fingers*
- Music - Play / pause: *Tap with two fingers*
- Music - Next / Previous: *Swipe left / right with two fingers*

Climate - Three fingers

- Fan speed: *Swipe left / right with three fingers*
- Temperature: *Swipe up / down with three fingers*

System - Four fingers

- Home: *Long press with four fingers*
- Show all applications: *Swipe up with four fingers*
- Switch between applications: *Swipe left / right with four fingers*
- Favourite applications: *Double tap with four fingers*
- Quit application: *Swipe down with four fingers*

Results from our research, has been summed into a set of guidelines, where it can be read that conforming to conventions is important when designing gestures, and if that is not a possibility the gesture needs to be user tested. When having a set of gestures it is preferable to have an underlying pattern for the gestures to be coherent and easier to remember. Further it was concluded that a gesture that is to be used often, should be simple.

The project has touched upon numerous areas of research. Having done initial acceptance tests for GABI, more tests have to be conducted to measure and compare the distraction and ensure safe interaction for the driver.

REFERENCES

AAM (Alliance of Automobile Manufacturers) (2006). *Statement of Principles, Criteria and Verification Procedures on Driver Interactions with Advanced In-Vehicle Information and Communication Systems*. Washington, D.C..

Armstrong, N. and Wagner, M. (2003*). Field guide to gestures: how to identify and interpret virtually every gesture known to man*. ed. Quirk Books.

Aveyard, H. (2010). *Doing a literature review in health and social care*. Maidenhead, Berkshire, England: McGraw-Hill/Open University Press.

Audi (n.d.). *MMI touch > A8 > Audi Sverige*. [online] Retrieved from: http://www.audi.se/se/brand/sv/models/a8/a8/equipment/multi_media_interface/mmi_touch.html [Accessed: 9 May 2013].

Audi Connect (n.d.). *Audi connect services*. [online] Available at: http://www.audi.com/com/brand/en/models/infotainment_and_communication/audi_connect_services.html [Accessed: 29 Jan 2013].

Beyer, H. and Holzblatt, K. (1998). *Contextual Design: Defining Customer Centered Needs*. Morgan Kaufman, San Francisco, CA.

Bischoff, D. (2007). *Developing guidelines for managing driver workload and distraction associated with telematic devices*. NHTSA Paper 07-0082.

Bogan, C. and English, M. (1994). *Benchmarking for best practices*. New York: McGraw-Hill.

Burns, P. et al. (2010). *The Importance of Task Duration and Related Measures in Assessing the Distraction Potential of In-Vehicle Tasks*. Proceedings of the Second International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI 2010), November 11-12, 2010, Pittsburgh, Pennsylvania, USA.

Cooper, A. et al. (2007). *About Face 3*. Wiley Publishing, Inc. Indianapolis, USA.

Designmodo (2013). *Principles of Flat Design.* [online] Available at: http://designmodo.com/flat-design-principles/ [Accessed: 10 Jun 2013].

Developer.android.com (n.d*.). Design | Android Developers*. [online] Available at: http://developer.android.com/design [Accessed: 6 Jun 2013].

Developer.apple.com (n.d.). *iOS Human Interface Guidelines*. [online] Available at: http://developer.apple.com/library/ios/#documentation/userexperience/conceptual/mobilehig/Characteristics/Characteristics.html [Accessed: 6 Jun 2013].

Djajadiningrat, T. et al. (2000). *Interaction Relabelling and Extreme Characters: Methods for Exploring Aesthetic Interactions*. Proceeding DIS '00 Proceedings of the 3rd conference on Designing interactive systems: processes, practices, methods, and techniques, pp.66-71.

Ericsson (2012). *Connected Car services come to market with Volvo Car Group and Ericsson - Ericsson*. [online] Available at: http://www.ericsson.com/news/1665573 [Accessed: 29 Jan 2013].

EC (Commission of the European Communities) (2008). *Commission Recommendation on Safe and Efficient In-Vehicle Information and Communication Systems: Update of the European Statement of Principles on Human Machine Interface*. Brussels, Belgium: European Union.

Fontana, A., & Frey, J. (1994). *The art of science. The handbook of qualitative research*, pp.361-76.

Ford (2013). *Ford Launches App Developer Program Marking New Course for Customer-Driven Innovation and Value Creation*. [online] Available at: http://media.ford.com/article_display.cfm?article_id=37551 [Accessed: 29 Jan 2013].

General Motors (2013). *GM Gives Developers a Whole New Sandbox, with Wheels*. [online] Available at: http://media.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2013/Jan/0108-sdk.html [Accessed: 29 Jan 2013].

Google, (2012). *Our Mobile Planet: Sweden - Understanding the Mobile Consumer*. [pdf] Available at: http://services.google.com/fh/files/blogs/our_mobile_planet_sweden_en.pdf [Accessed: 10 june 2013].

Green, P. (2000). C*rashes induced by driver information systems and what can be done to reduce them*. Proceedings of the 2000 International Congress on Transportation Electronics. Society of Automotive Engineers: Warrendale, Pennsylvania.

Harbluk, J. , Noy, I., & Eizenmann, M. (2002). *Impact of cognitive distraction on driver visual behavior and vehicle control*. Paper presented at the 81st annual meeting of the Transportation Research Board, Washington, DC.

Hart, S. (2006). *NASA-Task Load Index (NASA-TLX); 20 Years Later*. Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting, 904-908. Santa Monica: HFES.

Hart, S. & Staveland, L. (1988). *Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research*. In P. A. Hancock and N. Meshkati (Eds.) Human Mental Workload. Amsterdam: North Holland Press.

JAMA (Japan Automobile Manufacturers Association) (2004). *Guideline for In-Vehicle Display Systems.* Version 3.0.

Janlert, L. and Stolterman, E. (1997). The character of things. *Design Studies*, 18 (3), pp. 297-314.

Jones, J. (1992). *Design methods*. New York: John Wiley & Sons.

Jordan, P. (1998). *An introduction to usability*. London: Taylor & Francis.

Kahn, R. L., & Cannell, C. F. (1957). *The Dynamics of Interviewing: Theory, Technique, and Cases*. New York: Wiley.

Klauer, S., Dingus, T., Neale, V., Sudweeks, J. and Ramsey, D. (2006). *The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data*. DOT HS 810 594.

Lundgren, S. (2010). *Teaching and learning aesthetics of interaction*. Göteborg: Chalmers Univ. of Technology.

Lundgren, S. (2011). *Interaction-Related Properties of Interactive Artifacts*. Proceedings of Ambience '11.

Lundgren, S. and Gkouskos, D. (2013). *Escaping the obvious: Skewing properties of interaction*. Proceedings of Nordic Design Conference (NORDES) 2013.

Lewis, C. and Rieman, J. (1994). *Task-centered user interface design: A practical introduction.* Shareware book available at: http://hcibib.org/tcuid/tcuid.pdf

Maguire, M. (2001). *Methods to support human-centred design*. Int. J. Human-Computer Studies, 55 pp.587-634.

Mercedes-Benz (n.d.). *Concept A-CLASS connectivity.* [online] Available at: http://www5.mercedes-benz.com/en/tv/5518040_konnektivitat_en/ [Accessed: 29 Jan 2013].

Merriam-webster.com (2012). *Gesture - Definition and More from the Free Merriam-Webster Dictionary*. [online] Available at: http://www.merriam-webster.com/dictionary/gesture [Accessed: 14 Jul 2013].

Michalko, M.(2006). *Thinker Toys. A handbook of creative-thinking techniques*. Berkeley, CA:Ten Speed Press.

Msdn.microsoft.com (2013). *Windows Phone Dev Center*. [online] Available at: http://dev.windowsphone.com/en-us/design [Accessed: 6 Jun 2013].

Neale, V., Klauer, S., Knipling, R., Dingus, T., Holbrook, G. and Petersen, A. (2002). *The 100 Car Naturalistic Driving Study: Phase 1- Experimental Design*. DOT HS 809 536.

NHTSA (National Highway Traffic Safety Administration) (2012). *Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices*. Department of National Highway Traffic Safety Administration. Docket No. NHTSA-2010-0053.

Nielsen, J. (1994). *Heuristic evaluation*. In Nielsen, J., and Mack, R.L. (Eds.), Usability Inspection Methods, John Wiley & Sons, New York, NY.

Nielsen, J. (2012). *Thinking Aloud: The #1 Usability Tool*. [online] Available at: http://www.nngroup.com/articles/thinking-aloud-the-1-usability-tool/ [Accessed: 5 Mar 2013].

Nielsen, J. and Molich, R. (1990). *Heuristic evaluation of user interfaces*. Proceeding CHI '90 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp.249-256.

Norman, D. (2002). *The design of everyday things*. New York: Basic Books.

Patten, C. et al. (2003). *Mobiltelefonerande i trafiken (Vägverkets utredning om användning av mobiltelefoner och andra IT-system under körning)*. [online] Available at: http://www.cellphonefreedriving.ca/media/VV_mbl_slutrapport_2003_(1.03).pdf [Accessed: 12 Mar 2013].

Plato. and Jowett, B. (n.d.). *Timaeus*. Champaign, Ill.: Project Gutenberg.

Preece, J., Rogers, Y., & Sharp, H. (2002). *Interaction design: beyond human-computer interaction*. New York, NY, J. Wiley & Sons.

Riksdagsförvaltningen (2013). *Trafikutskottet vill förbjuda användning av kommunikationsteknik vid bilkörning som kraftigt försämrar uppmärksamheten - riksdagen.se*. [online] Available at: http://www.riksdagen.se/sv/Start/Press-startsida/pressmeddelanden/201213/Trafikutskottet-vill-forbjuda-anvandning-av-kommunikationsteknik-vid-bilkorning-som-kraftigt-forsamrar-uppmarksamheten/ [Accessed: 12 Mar 2013].

Saffer, D. (2008). *Designing Gestural Interfaces*. Sebastopol: O'Reilly Media, Inc..

Seemann, J. (2012). Hybrid Insights: Where the Quantitative Meets the Qualitative. Rotman Magazine, Iss. Fall 2012 pp. 57-61.

Semcon. (2013a). *This is Semcon.* Available: http://www.semcon.com/en/Om-Semcon/. [Accessed 31th May 2013].

Semcon. (2013b). *Organisation*. Available: http://www.semcon.com/en/About-Semcon/Vision-and-strategies/Organization/. [Accessed 31th May 2013].

SFS 1998:1276. *Trafikförordningen*. Stockholm: Näringsdepartementet. 2 ch. 1 §.

Shneiderman, B. (1983). *Direct Manipulation: A Step Beyond Programming Languages*. Computer. 16 (8). pp.57 – 69.

Teslamotors.com (n.d.). *Model S Features.* [online] Retrieved from: http://www.teslamotors.com/models/features #/interior [Accessed: 9 Feb 2013].

Tidwell, J. 2006. Designing interfaces. Beijing: O'Reilly.

Tsimhoni, O. and Green, P. (2001). *Visual demand of driving and the execution of display-intensive, in-vehicle tasks*. Proceedings of the Human Factors and Ergonomics Society 45th

Annual Meeting. Santa Monica, CA. Human Factors and Ergonomics Society. pp. 1586-1590.

Varcholik, P. D. (2011). *Multi-touch for General-Purpose Computing: An Examination of Text Entry*. Doctoral dissertation, University of Central Florida Orlando, Florida.

Ware, C. (2004). *Information visualization.* San Francisco, CA: Morgan Kaufmann.

Wickens, C. (2002). *Multiple resources and performance prediction*. Theoretical Issues in Ergonomics Science, 3 (2), p.159-177.

Appendix I BENCHMARKING

What follows is a table of the brands and models visited during the benchmarking session.

Brand	Model
Audi	*A8*
Ford	*Mondeo*
Hyundai	*i40*
Kia	*cee'd*
Lexus	*GS 460*
Mercedes-Benz	*A-class*
Porsche	*Panamera*
Renault	*CLIO*
Tesla	*Model S*
Toyota	*Prius*
Volkswagen	*Beetle* *Golf* *Passat* *Sharan* *Touareg*

Appendix II EXISTING GUIDELINES

Introduction

The underlying guideline material for this is both coming from existing guidelines developed for designing in-vehicle information systems (IVIS), originating from different instances. However, they are not developed specifically for touch or in some cases not specifically to a driving context. Nevertheless, many of them they can still be applied on an IVIS with a touch screen, since often the core principles are the same, both interface- and interaction-wise. These guidelines are not laws but are rather recommendations to conform to. The other part of the underlying material for this document is originating from the result of this master thesis, this part concerns the use of gestures in IVIS.

There are four different instances from where this document originates. First is NHTSA (2012), which is the National Highway Traffic Safety Administration of the United Stated Government. The second source is the guidelines of European Commission (EC, 2008). Third is the Japan Automotive Manufacturers Association (JAMA) (JAMA, 2004). The forth set of guidelines are the Alliance's guidelines (AAM, 2006), which is the Alliance of Automobile Manufacturers' (from now AAM) response to a challenge by NHTSA to address the rising concerns of distraction while driving. It is upon these NHTSA having based their guidelines resulting in the guidelines being similar in many cases.

General recommendations

One of the most important tasks of an IVIS is to be transparent enough not to yield another distraction object for the driver and to avoid creating potential hazardous situations (EC, 2008, p. 7; EC, 2008, pp. 7-8; JAMA, 2004, p. 1; AAM, 2006, p. 9). This has been formulated in different ways in the different set of guidelines, here is the AAM's formulation:

> *"Systems with visual displays should be designed such that the driver can complete the desired task with sequential glances that are brief enough not to adversely affect driving"* (AAM, 2006, p. 38)

The IVIS should be also be designed to not distract the driver by using visually entertaining material on the screen (AAM, 2006, p. 9; EC, 2008, p. 8; JAMA, 2004, p. 1) and should always strive towards having as small effect on the driver performance and attention as possible.

This also includes the physical space in the vehicle; the forward view or any controls should be obstructed by either the placement of the physical device. (JAMA, 2004, p. 1; NHTSA, 2012, p. 133)

Glances

Driving is a task requiring much attention from the driver and a secondary task must not draw the attention from the primary driving task. Due to this there are guidelines concerning different time and glance aspects that can be measured while driving. The AAM also states that their guidelines can be revised if research presents new information (AAM, 2006, p. 39). What follow are three numerical variables concerning time aspects:

Total glance time (TGT)

The summary of the glance durations to complete a task. The recommendations for the TGT are to be less than:

- 8 seconds (JAMA, 2004, p. 7)
- 12 seconds (NHTSA, 2012, p. 10)
- 20 seconds (AAM, 2006, p. 39)

Singe glance duration (SGD)

The time for a specific glance on the screen. The guideline for this is that the maximum SGD should not exceed 2 seconds. (NHTSA, 2012, p. 10; AAM, 2006, p. 39). This value originates from the 100 car naturalistic driving study where indications of glances over two seconds increases the risk of crash or near-crash events (Bischoff, 2007).

Total shutter opening time

Coupled to occlusion methods for testing. These recommended values should not be exceeded and differs from organisations:

- 7,5 seconds (JAMA, 2004, p. 7)
- 9 seconds (NHTSA, 2012, p. 11)

To achieve a complete estimation of the distraction risk Burns et al. (2010) argues for the importance of utilising the TGT as a part of the evaluation. Estimating using solely the SGD might have a misleading effect of the distraction evaluation.

System behaviour

The overall goal for the system is to not interfere with controls or displays in the vehicle that are used for the task of driving and road safety (EC, 2008, p. 24). Information about potential malfunctions compromising the safety should be presented to the driver (EC, 2008, p. 25).

Feedback

The importance of feedback is prominent from this master thesis. All the different stages of evaluation and user studies have all highlighted that good feedback is needed to enable minimised distraction. Feedback is the system’s way of talking to the users and acknowledge their actions. It is critical to give appropriate feedback at the right time.

> *“The system’s response (e.g. feedback, confirmation) following driver input should be timely and clearly perceptible” (EC, 2008, p. 21; AAM, 2006, p. 74)*

This is a shared view of the feedback given by the system. The response time has a numerical value of 250 ms (NHTSA, 2012, p. 138-139), however Saffer (2008) and Cooper et. al. (2007) suggest a value of 100 ms for the system to provide feedback. This value is for the user to experience an action as instantaneous. To enable feedback without visually distraction while driving auditory or haptic feedback, such as vibrations, is permitted (JAMA, 2004, p. 14).

Consistency

When designing computer systems, coherency is one of the most important factors for a system to feel cohesive and complete. Coherency can often help users to comprehend the complex by providing an inner logic, a solid ground that the rest builds upon. One of the most prominent profiles within usability, Nielsen (1994), lists coherency as one of the most important usability heuristics. Within HCI, coherency is often discussed as being the basis for a functional system (Beyer & Holzblatt, 1998). As Lundgren suggests:

> *"Coherency - in its widest sense - is to strive for harmony and unity in design using some kind of underlying rationale for design - be it based on mathematics, adaption to functionality, personality or something else." (Lundgren, 2010, p. 101)*

Lundgren (2010) suggests that numbers or narrative may be used to achieve coherency. Numbers can provide symmetry by applying mathematics as the underlying logic and the approach can be traced all the way back to Plato's description about how the soul is created via complex calculations:

> *"In this manner there were formed intervals of thirds, 3:2, of fourths, 4:3, and of ninths, 9:8…" (Plato and Jowett. B, n.d., p.19)*

With an underlying narrative as a basis for design, objects may be given an *"istoria"* (Alberti, 1435). Janlert and Stolterman (1997) suggest that complex things and systems may be easier to understand if they were given a certain character.

Error handling

A general computer system should be designed so that the user cannot make errors. If an error occurs the system should always take the blame. (Cooper et al. 2007) This is what an IVIS also should strive for but might not always be applicable since it is placed in a critical context. Making error input impossible is a good way to make the input interaction time more effective. Instead of typing, pressing, dragging leading to an error (message) and having to redo these actions, it is only possible to interact in a non-error way.

The message should also be user centred and take the blame for the error. The information in the message should be constructive and informative. The system should allow reversible actions, this can be used instead of having confirmation messages the system (Cooper et. al., 2007).

System sounds

The sound levels of the system in the car should be able to be controlled by the driver. This control does not affect the alarm system. (JAMA, 2004, p. 3) The system should not be able to produce sounds which might cancel out alarms or warnings, but the system sound should not be annoying or irritating (JAMA, 2004, p. 3; AAM, 2006, p. 63; EC, 2008, p. 16, NHTSA, 2012, p. 137) The volume control is for the drives who consider the auditory information as distraction and wants to turn the volume of it down, or off. (JAMA, 2004, p. 3)

System interaction/interface with displays and controls

The drivers' main task is to drive the vehicle safely, avoid accidents and control the vehicle. To be able to do this it is important that the secondary tasks do not limit the drivers' ability to focus on their main task. The drivers should, at all times, be able to shift focus from the secondary tasks if the traffic situation is demanding focus, or whenever necessary. (JAMA, 2004, p. 3).

Controls

The aim of the controls is that the controls should help the drivers to interact with the system in the vehicle while being as transparent as possible impacting the primary driving task as little possible.

> *"System controls should be designed in such a way that they can be operated without adverse impact on the primary driving controls." (EC, 2008, p. 20)*

It is also important that the controls to be used in the vehicle while driving are suitable for that specific task, hence keyboards or controls that require fine controls or adjustment are not recommended in the vehicle. (NHTSA, 2012, p. 70)

Hands

The driver should always be able to keep at least on hand on the steering wheel. This leads to controls using visual-manual interaction should require no more than one hand to operate. (JAMA, 2004, p. 3; AAM, 2006, p. 67; EC, 2008, p. 17; NHSTA, 2012, p. 11, p. 137)

Front View

The location of the display should not obstruct the view of the drivers, neither should the use of IVIS: buttons, touchscreens or gestures, obstruct the drivers' field of view. (JAMA, 2004, p. 3; NHTSA, 2012, p. 133)

Functionality Disabled

When designing for an IVIS it might be preferable to divide the functionality depending on the context, for example if the vehicle is moving or not. Using such context-aware functionality it is important to make these functions unavailable when they are not intended to be used. Making them inoperable is the preferred solution but if it is not possible there is the option to provide clear warning against the unintended use (JAMA, 2004, p. 4; EC, 2008, pp. 23-24; NHTSA, 2012, p. 139).

Task, which requires long un-interruptable steps of interaction, should be disabled when the vehicle is in motion. These long interactions could for example be tasks that require more than six steps. This is recommended by NHTSA (2012, p. 70, p. 136) who suggests a maximum of six steps, based on the SGD of 2 seconds and the TGT of 12 seconds.

Scrolling text and letters should be avoided in an IVIS. (NHTSA, 2012, p. 70, p. 136; JAMA, 2004, p. 7) Further it should be prohibited to display more than 30 characters (NHTSA, 2012, pp. 69-70, p. 136) or 31 characters (JAMA, 2004, p. 7) (not counting punctuation marks, numbers and units are counted as one character no matter how many digits). This numbers are intended to prevent tasks such as reading text messages, Internet browsing, reading electronic books (NHTSA, 2012, pp. 69-70)

The NHTSA guidelines (2012, p. 116) contain a list of visual-manual activities that should be locked out while the vehicle is moving:

- Visual-manual text messaging,
- Visual-manual internet browsing,
- Visual-manual social media browsing,
- Visual-manual navigation system destination entry by address, and
- Visual-manual 10-digit phone dialling

These guidelines furthermore recommends the lock out of displaying photographic or graphical moving objects such as showing videos or video phone calls, which are not related to driving. Objects that can be considered as driving related are for example route planning and information about the route or emergency information. (NHTSA, 2012, pp. 69-70)

Disruption in time

An IVIS should in general be designed so that the driver can be in control of the pace of the interaction in the system. The system should never require the driver to make time-critical decisions when providing input to the system. If the driver interrupts the ongoing task, it should be possible to resume the task at the same logical point. (JAMA, 2004, pp. 3-4; AAM, 2006, p. 69, p. 71; EC, 2008, pp. 18-19) Say for example if the driver is using the navigation by navigating to an address, but wants to change playlist by entering the music application. Returning to the navigation application the navigation should continue to the previous route, instead of the driver having to enter the address again.

When designing for IVIS, long sequences of interactions, involving many tasks, should be avoided, NHTSA recommends maximum of six tasks (NHTSA, 2012, p. 70, p. 136).

Menus

Cooper et. al. (2007) states that most navigation in software is excise. From the users' point of view, navigation is often an unnecessary step to reach their goal. Unnecessary and complicated navigation makes the users frustrated, and poorly designed navigation in systems is a common problem.

Often used functions should have a button or key assigned for quick access, rather than being located in the menu structure (Cooper et. al., 2007).

Other

The driver should be informed about the system status. This information concerns malfunctions and status that are likely to have an impact on the safety of the vehicle (NHTSA, 2012, p. 140). This information needs to be presented in an easily and quickly understandable way (JAMA, 2004, p.4).

Information presentation

What is important in the area of information presentation, and especially important in a driving context, is to present the information in a clear and understandable way, so that the perceiver, here it are the drivers, can assimilate the message in the information using only a few short glances. This is formulated by the EC (2008) as:

> *"Visually displayed information presented at any one time by the system should be designed in such a way that the driver is able to assimilate the relevant information with a few glances which are brief enough not to adversely affect driving." (EC, 2008, p. 13)*

The presented information should not be complex may not cause potential hazardous behaviour or impair the road safety. (EC, 2008, p. 8; JAMA, 2004, p. 2) The display of the information should also be timely and relevant. (EC, 2008, p.15; AAM, 2006, p.63) The information to present can also be prioritised, and if so, information concerning safety should be given higher priority (EC, 2008, p.15) and be presented in a simple, accurate and clear way (JAMA, 2004, p.4).

Attention

When presenting information, techniques for attention seeking should be avoided. Examples of techniques to avoid are blinking objects and too bright colours which both attract attention (Cooper et. al. 2007). The information on the screen should not cause the drivers to look at it (JAMA, 2004, p. 3), for example reading scrolling text results in the reader staring at the screen and should thus be avoided.

Data volumes

If presenting larger data volumes than the 30-31 characters mentioned in Functionality Disabled it is preferably to chunk the information and display it in smaller pieces to avoid gazing at the display. Doing this the information is easier to read and the driver can decide the reading pace. (JAMA, 2004, p.3)

Information not to be viewed

If the IVIS provides non-safety related information, this information should either be turned off while the vehicle is moving or it should be presented in a way so it is not provided to the drivers. (AAM, 2006, p. 74; EC, 2008, p. 2)

Icons / Symbols

To ease and enable for quick interpretations in the IVIS, internationally agreed standards for icons, symbols, acronyms, abbreviations, legibility and words should be conformed to. (AAM, 2006, p. 61; JAMA, 2004, p. 2; EC, 2008, p.14) If there is no standard for an object it is relevant to apply design guidelines or conduct user studies to validate the representation of the object (AAM, 2006, p. 61).

Button sizes and distances

Reading the design guidelines from iOS (Developer.apple.com, n.d.), Android (Developer.android.com, n.d.), and Windows Phone (Msdn.microsoft.com, 2013), the recommended minimum touch target should be 40-48pt, which means that the physical touch area should be approximately 1x1 cm. Saffer (2008) suggests that this area should be 150% enlarged to allow most people to be able to interact with good precision. In a driving context, one's precision is worse than using a smartphone or tablet, and it is even more important that the precision is accurate. Hence, we recommend the size of the touch target to be at least 1.5x1.5 cm, but preferably even 2x2 cm.

Appendix III SCAMPER

SCAMPER was used early in the process to generate ideas and possible new concepts. This was performed by analysing the infotainment system of a Volkswagen Golf. The system was not chosen because of any characteristic attributes, but because it reflected the majority of infotainment systems and their distribution between touchscreen and physical buttons.

Results

The results of the SCAMPER session are presented below.

Substitute

In the substitution part there were many alternatives to using a rotary controller, physical navigation buttons, volume button, and individual fan buttons. All of these were found to be exchangeable and could instead be controlled using gestures. All controllers and their possible substitute were the following:

Rotary controller

- Touchpad
- Steering wheel
- Steering wheel thumb joystick
- Direct touch control (just remove it)
- Mouse
- Scrolling ball

Navigation buttons

- Gestures
- Tabs
- Dashboard
- Physical rotary controller

Volume / Power

- Gesture
- Touch zone
- Slider
- Separate physical buttons

Individual fan control

- Rotary controller
- Touch zones
- Gestures
- Multi level button/indication

Climate / comfort

- Touch zone (specific zone)
- Gestures
- Own view/app

Combine

Next question that followed in the SCAMPER list was how things could be combined. Below is a list of the combinations that were suggested.

- Volume/Power + Rotary selection controller
- Screen + Rotary selection controller + Climate buttons
- Navigation buttons + Touch = Dashboard
- Navigation buttons + Rotary selection controller
- Climate buttons + Touch screen
- Fan controls = Merge into one

Adapt

Considering how the system could be adapted to other technologies, for example Microsoft Kinect[12] or Leap Motion[13] which would incorporate free-form-gestures to control the functionality of the infotainment, produced the following results.

- Kinect / Leap motion - Free form gestures
- Kameleon - Change colors and brightness depending on light conditions
- Kindle - E-Ink screen
- Screen readers (Accessibility) - Read content on screen
- Magnifying glass - Magnify parts of the interface
- Games - Gamify things like safe driving or eco-driving
- iOS do not disturb feature / Minimal writing applications - Focus driving

Modify / Magnify

How could the system be modified or components magnified to change the systems' attributes?

- Magnify the screen - easier to interact with.
- Magnify the volume controller, since it's the most important object, and make stand out.
- Navigation buttons could be bigger and thus fit both text and icons.

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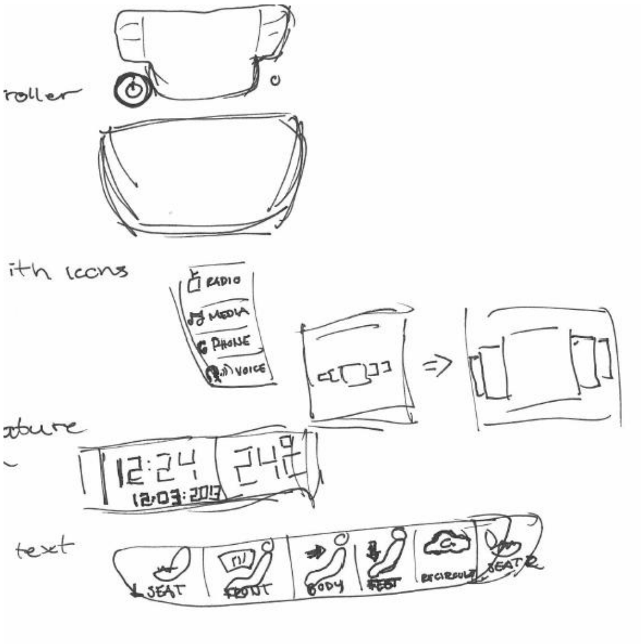
[12] http://www.microsoft.com/en-us/kinectforwindows/
[13] https://www.leapmotion.com/product

- Dashboard could have bigger app icons, similar to Apple's' cover flow.
- Time and temperature could have a separate screen which would allow the drivers to see the time with a single short glance.
- Climate buttons can be made bigger and thus also fit both text and icons.



Concept drawing from Modify/Magnify

Put to other uses

Rotary controller

- Windows
- Speed
- Turn
- Zoom
- Temperature
- Horn

Navigation buttons

- Change between driving modes
- Horn

Touch panel

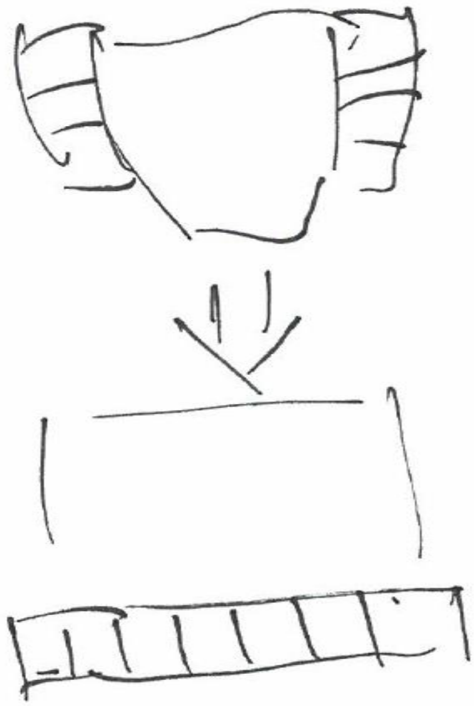
- Set/adjust speed limiter
- Change light mode
- Adjust mirrors
- Windows
- Seat heating
- Seat adjustment

Eliminate

- Rotary selection controller
- Navigation buttons (Keep menu?)
- Can fit a bigger touchscreen instead
- Small temperature displays
- Could be shown on the actual button or on the main display

Rearrange

- Navigation buttons at the bottom instead
- Move everything up and move fans



Concept drawing of Rearrange

Appendix IV SKEWING

To generate concepts and develop new features, skewing was used. The analysis of the system, an infotainment system from a Renault Clio, was done using Lundgren's (2011) list of interaction related properties. The list covers attributes related to behaviour, complexity, interaction etc. and helps analysing the system from many different aspects. Five of the properties were then chosen as the most prominent ones. These properties were:

- Approach
- Behavior analysis
- Connectivity
- Locality of users
- Openness

Lundgren's (2011) definition of **Approach** is *"Which interactive stance the artifact takes towards the user"(p. 5)* and the range is set from *submissive* to being either *suggestive* or totally *dominant.* The system was at this point considered submissive and should thus be skewed towards acting dominant, telling the user what to do and how to do it.

Behaviour analysis specifies *"To which extent a user's actions are recorded, remembered and or analysed" (Lundgren, 2011, p. 7)* and ranges from *inactive* to *active* or *exploiting*. The system remembers the driver's last routes and points of interests in the navigation application, saves the last radio station listened to and saves devices paired with the system. Thus, it was considered active with the goal to skew it towards exploiting.

Connectivity is defined by Lundgren (2011) as *"To which extent an artifact is connected to other artifacts" (p.8)*, and this system was thus considered an independent system. The total opposite would be to have it networked and connected to all other systems somehow. Therefore, the aim of the connectivity skewing was to make it networked.

Locality of users treats *"How users who are communicating or collaborating are located in relation to each other." (p.8)* Since the car and the infotainment system had no connectivity whatsoever to other systems, cooperation and communication had to be done at the same location. This should thus be skewed to use distant communication and collaboration.

Last property was ***Openness***. The system was very much restricted in terms of what could be changed or customizable in the car. Albeit the ability to change things like sounds when interacting with the system, screen brightness and save favourite radio stations and destinations, the system was considered closed with only a few possibilities for customisation. Hence, the system should be skewed towards being *changeable* and in best case *codeable*.

All properties and towards what direction they should be skewed was put up on a whiteboard. For each property as many features as possible were generated and written next to their corresponding property. At this point no concept or idea was declined for being too farfetched or not realisable.

Following, the features that was considered most interesting and promising was developed further by sketching them, trying to visualise a scenario for how it would work.

Results

The following concepts and sketches are all outcomes from the skewing exercise and was used as inspiration when designing new concepts for how the car could interact with the driver's personal artefacts, such as cell phone, computer or tablets. Some outcomes were also incorporated, together with concepts and outcomes of other test and workshops, into new design concepts.

Approach - Dominant

The infotainment system decides when it is safe for the driver to interact with it and will, in case the driver tries to interact with it in an inappropriate situation, warn the driver and prompt a message telling the driver to keep attention to the road and the driving situation instead of using the infotainment system.

Behaviour analysis - Exploiting

This concept relies on the system analysing the user's behaviour and daily patterns. Depending on what time and day it is, the system knows where the user, with different probability, is headed. The system prompts the user with assumptions where she is headed and the user can chose to accept one of the suggestions if she wishes to start navigating there. Many drivers' daily pattern looks similar each day so the system will also make the assumption that something is wrong if things differ from the usual schedule. This may result in the system messaging the user, warning her that she might have overslept or that she is not paying attention while driving and misses a turn.

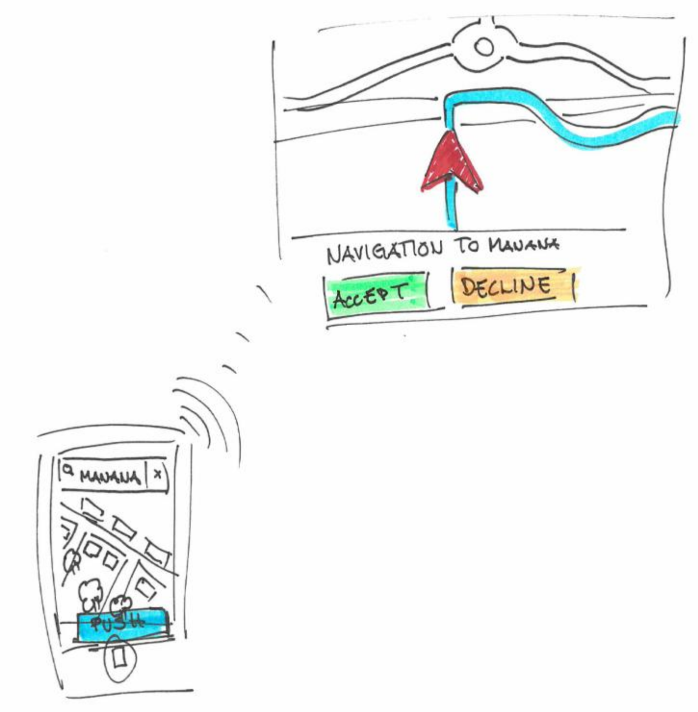
It can also recommend restaurants or interesting places the user might want to visit, which relies on previous stops and reviews made.

Concept drawings of Exploiting

Connectivity - Networked

To connect drivers and users of the infotainment system a few features were added; Audio instant messaging, multiplayer games and the possibility to challenge each other in different ways, user profiles with statistics.

The audio message service allows users to record voice messages and send to a contact instead of ordinary text messages. The receiver can listen to the message and answer it whenever the situation allows doing so. This system combines the advantages of texting with the ones with ordinary phone calls. Thus it allows the user to keep her eyes on the road at all times while having a conversation with a friend or family.



Concept drawing of a pushing route from mobile device to the car

To improve the driving experience by avoiding traffic jams and heavily congested roads, the possibility to share information about accidents and road works was added. This feature is tightly coupled to the systems behaviour analysis, since it will prompt the user with questions and information whenever something deviates from the usual. The system might for example prompt something similar to *"It seems like you are stuck in a traffic jam, is this correct?"* and the driver can answer this question, which then will be shared with other drivers using the same system, warning them and recommending to take another road.

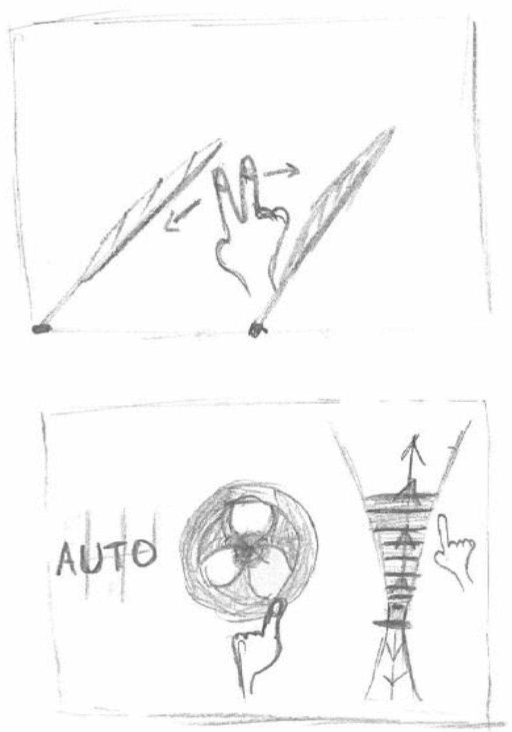
Locality of users - Distant

To allow users to collaborate and communicate with each other, the previously mentioned messaging also includes communication between the in car system and smartphones and tablets, through a specific application. A voice message can be recorded from anywhere and sent to the car, simply by having this application on one's own device.

Not only is the system able to receive messages from other users, but the user or friends of the user are able to "push" information from her mobile devices. This usage can be incorporated in many different applications, the figure above demonstrates how this feature can be used to push routes or directions to the car when searching from a mobile device or a website.

Openness - Changeable / Codeable

In this concept the users have full access to the car, meaning that information about the car can be retrieved and used, and the car can also be controlled. Here anyone, preferably a programmer, can create applications for his or her own car, to for example control the steering of the car, or the car's accelerate- and break controls, see figure to the right.



Concept drawing of Changeable/Codable

ANALYSIS

The motivation for the use of this method was to develop new concepts, where parts might be considered useful in the final version. Due to the re-focusing of the project the concept generation fell out of scope to give space for further investigating gestures.

Some of the results from the skewing session could however be considered relevant. In the first skewed property the importance of attention to the road is prominent. The system becomes an active guard to secure the drivers view on the road, hence minimising the visual distraction. In the second concept the users could program applications to use in their cars, having full access to their cars. However, this is not suitable in a vehicle, but the underlying thought is interesting, that the user can program or customise own gestures or favourites. In order to create own applications for own vehicles, the manufacturers have to make sure that the vehicles are protected against exploiting in the system.

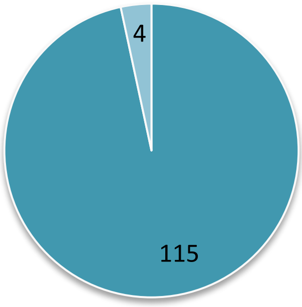
What could be concluded from the skewing session were that it is good if the system can warn the driver if he or she becomes distracted from the road and that a changeable or even codable system could be interesting, but it has to be restricted.

Appendix V SURVEY ABOUT IMPORTANCE OF THE FEATURE CONTROLS IN THE CAR

119 responses

General information

1. **Do you have a driver's license?**



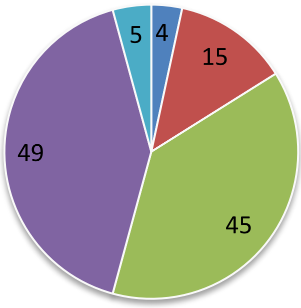
Yes	115
No	4

2. **How old are you?**

28 26 25 32 25 26 26 24 25 27 25 25 24 24 23 27 26 2729 25 23 27 26 25 23 29 25 26 27 28 24 28 36 25 28 24 24 30 32 25 25 25 26 51 28 26 24 25 27 49 59 29 28 28 53 30 23 27 37 37 25 26 25 49 36 33 38 27 47 47 32 25 62 29 27 36 28 30 36 42 25 40 28 24 37 36 33 38 30 30 38 31 31 39 59 44 30 34 46 36 29 27 27 24 31 38 41 25 32 45 35 34 27 24 32 30 29 30

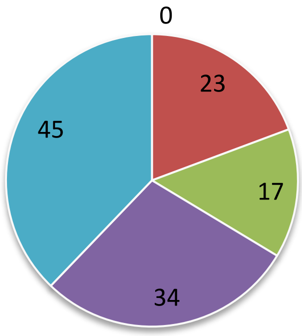
Max	62
Min	23
Avg.	31,2

3. **For how many years have you had your driver's license?**



< 1	4
1-5	15
6-10	45
> 10	49
Unspecified / Without driver licence	5

4. **How often do you go by car?**



Never	0
A few times a year	23
Once a month	17
A few times a week	34
Every day	45

Controls in the car

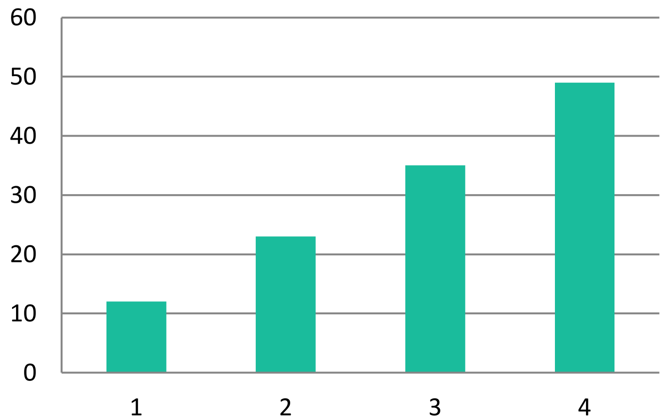
The following questions concern controlling features in the car, some more common than others.

Rate the importance of easy/fast access to the controls of each feature

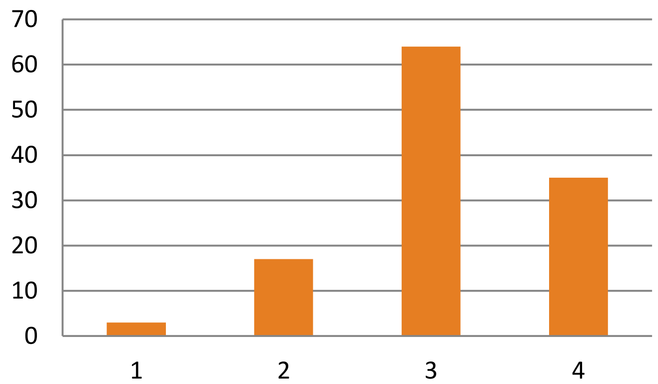
Please rate according to your own preferences on the scale 1-4, where **1 is "Not important" and 4 is "Critical".**

The result is presented having the scale on the X-axis and number of participants on the Y-scale.

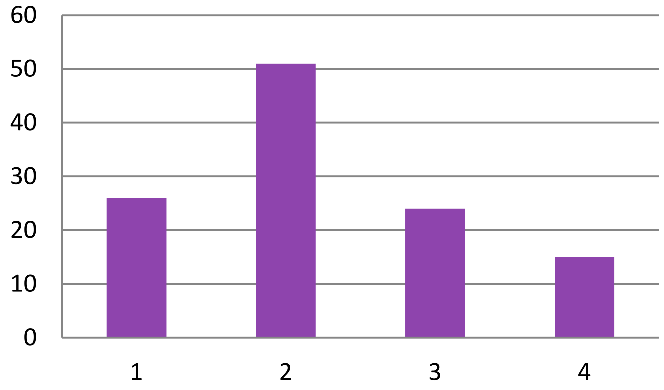
1. **Hazard warning lights button**



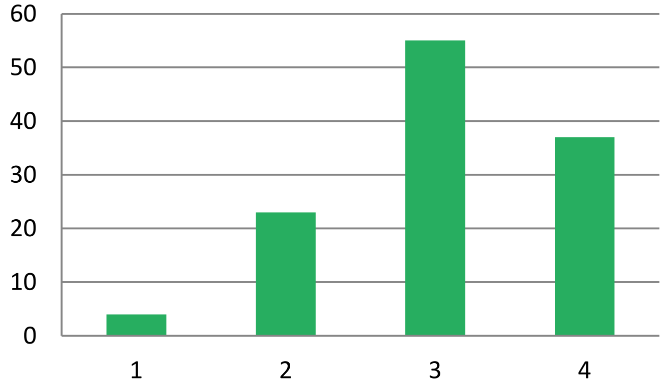
2. **Climate Control**



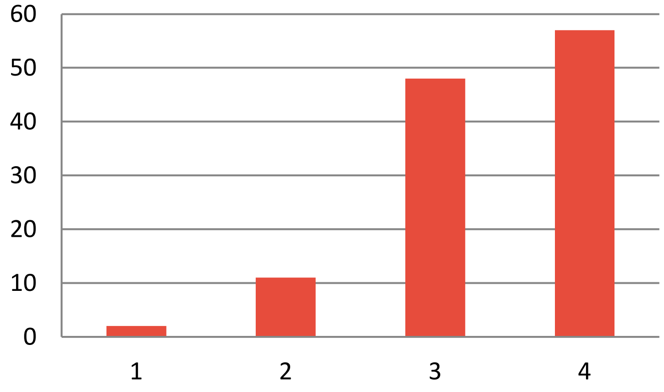
3. **Air Recirculation**



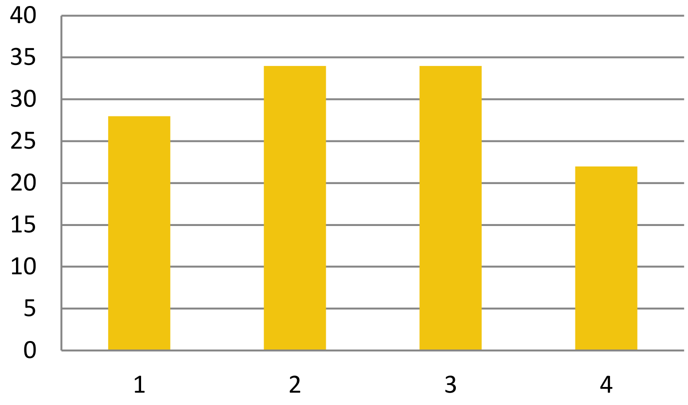
4. **Radio / Music**



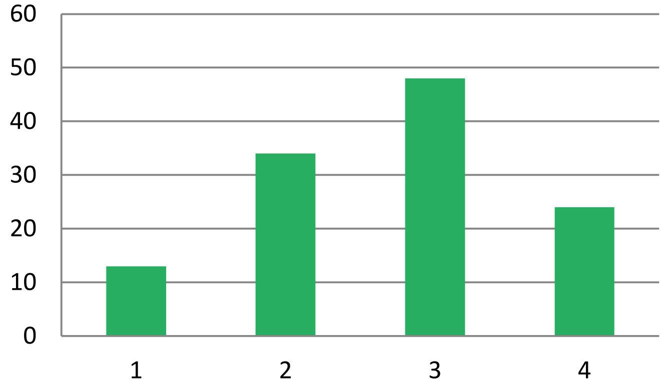
5. **Volume**



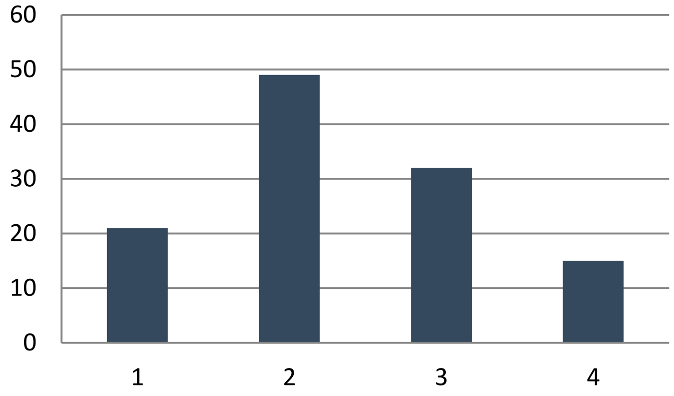
6. **Telephone**



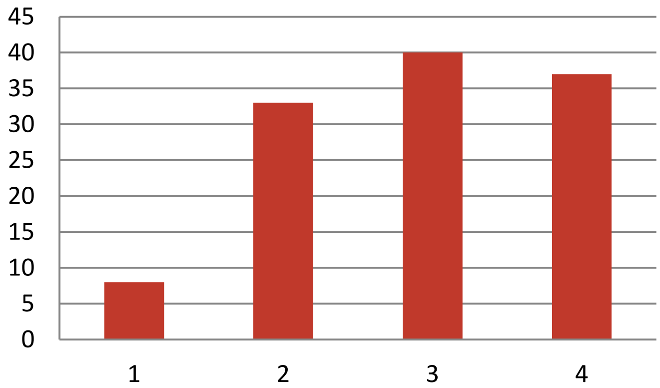
7. **Navigation**



8. **Seat heating**

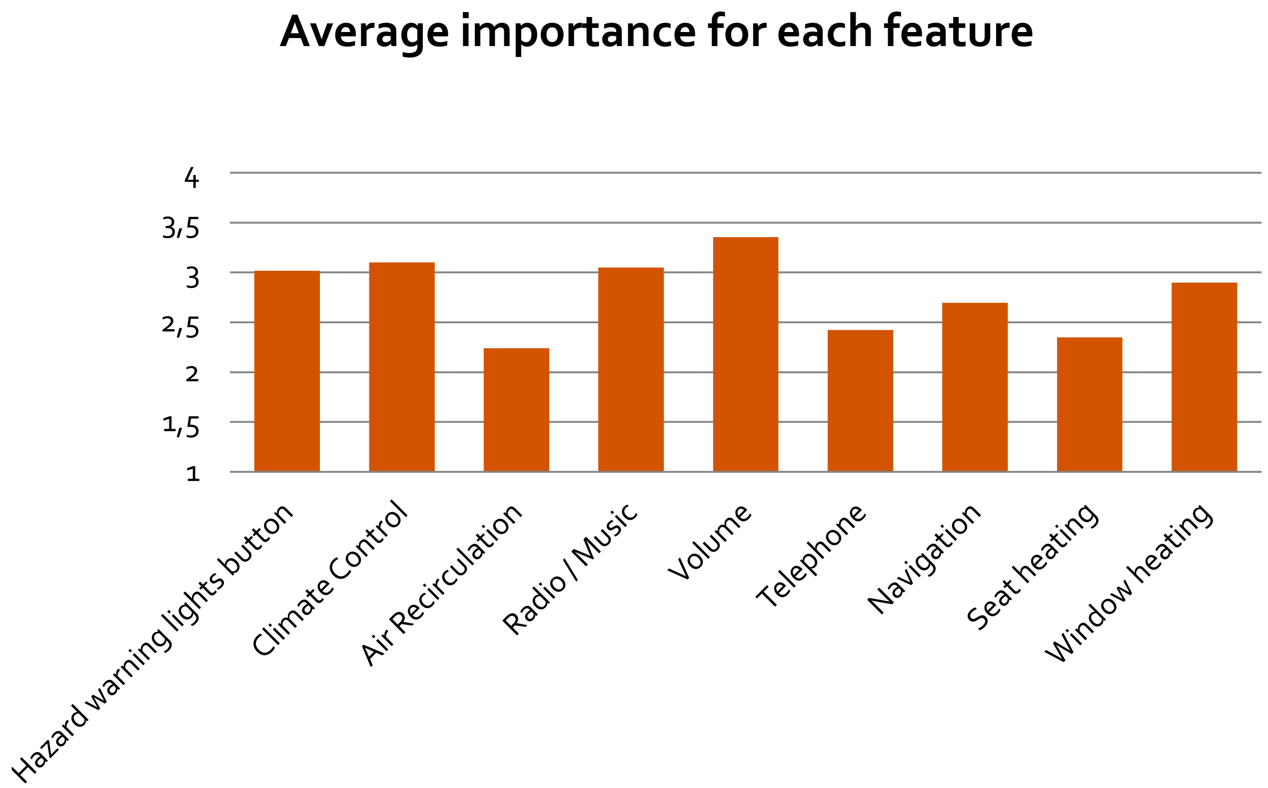


9. **Window heating**



Other comments

A easily controled Cruisecontrol / radar control is more important than above mentiond controles. Also window-whipers and settings for them are more importent, Other things that I rate more important than above things is Highbeem/ lowbeem - often in conflict with the cruiscontrole lever. Electronic gearchangse and transmition settings if the car is equvipet with that. and chassi electronics like airsuspention settings and ESP wide slip and OFF I dont know the purpuse with this servey, maybe you are asking the wrong questions? From my experience from driving clinics at Volvo in the same subject, I think you have to list mutch more diffrent funktions to get a usefull result. Also, many people dont know what control they use the moste.... com what a great feature it would be if it was possible to get your lights to follow your eye movements in turns etc just by looking at the windscreen... Usually at least in the cars I had and drov,e some of the controls to manage the active safety systems (ESP on/off, ASR on/off, etc.. note: that the anachronism can be different depending the brand) are close to the central console and I wish they could be closer to the wheel or in the best case to be configurable through the IVI. Good Luck! Important that the controls are distinct and easy to use without needing much visual attention. Needs to be possible to access at least partly by the sense of touch. Switching between low beam and high beam (halv-hel ljus). Differs sometimes between carmodels. controld Farthållare är någonting som borde vara enklare att hitta då man alltid kommer på att man vill sätta på den när man redan kör på motorvägen i 110. Därmed blir det lite halvfarligt när man letar efter den samtidigt som man måste ha koll på trafiken Parkingbrake control!! Things that are done often and during drive should be easily available. Things that can be done before actually moving the wehicle can be a bit more difficult to find/reach/maneuver. Things, such as the hazard warning lights button, that are used only under certain conditions can afford to be secondary. Turning Lights (Blinkers) - important Full/Half headlamps (Hel/halv-ljus) - Critical Mute button, when listening to media that is not live radio. If You are listening to a book, You don't want to turn the volume down, You want it to pause. Controls for making a phone call is not as critical (when it comes to fast access) as buttons for answering / declining an incoming phone call. Since the head lights control moved from joystics on the steering whell base, to knobs on the left side of the steering wheel , the importance of fast and easy access is very high. Also easy and fast access to rear door locking and rear windows are important especially for families with children on the back seat. Another importan control is the button that heats up the rear windshield. Cruise control should be easy to access and control. I would rate it #3 Hade svarat "A few times per month" på frågan: "How often do you go by car?" om det alternativet hade funnits. :) One of the most importent aspect I would would be blue tooth and parking sensors Hmm.... cruise control buttons..?? :-) Very critical to me.... but maybe you have not included driver support functions (turn indicators, wipers, cruise etc.) Steering column / steering wheel mounted controls are very useful to change things without taking your eyes from the road. IP mounted touch screens are dangerous, distracting and frustrating when you have to move/search slowly through different menus. Physical buttons are much quicker to operate than touchscreen systems, and therefore safer when driving. Cruise Control is essential to me. I use it all the time and when having a rental car with unlogical function of that, the car is banned from my list of possible purchases. windshield wipers - if you cannot see, you cannot drive horn - to warn other drivers (it depends on which country you are from - look at how often they use it in southern Europe vs. Nordic countries) if you want one that is obviously critical: the horn ;) Anyway I personally think the phone buttons are useless, because I won't call while driving. But for people who do they would be important. Overall I like the way things are positioned in my car, though I'd appriciate if it was easier to use my some of the features in my phone while driving (making calls, sms, GPS etc.) 1. Window Roll and lock Controls - should be easily accessed by non-gear stick handling hand 2. Doors lock/unlock control - should be easily accessed by non-gear stick handling hand ..button for the lights in the fog in front or rear..I always change between them when for example I need only the rear strong red light to warning people behind me, I press the button that turns on the front fog lights. Gör det röststyrt!



Appendix VI WORKSHOP

As a part of the ideation phase a workshop was conducted with the aim of generating design concepts and ideas for an infotainment system. There were eleven participants with mixed backgrounds, both with and without design as a profession but generally computer literate, in the ages of 18 to 37 participating in the workshop. To encourage creativity Extreme Characters (Djajadiningrat et. al., 2000) was used. The participants were divided into three groups, combining different backgrounds providing several perspectives to the upcoming tasks. The extreme characters were chosen to enable and demand extreme types of interaction and burst the bubble of how things should look and work in a vehicle. Each group worked with one of the following characters:

- Yoda, from Star Wars
- Winnie the Pooh
- Rex, from Toy Story

With these characters in mind, the groups started to analyse their characteristics, abilities and restrictions that described the character. If a group was uncertain of something about their character they were encouraged to make assumptions, as long as they noted or mentioned what assumptions they did. The analyses were performed with the following aspects consider:

- Ways of interacting
  - restrictions
  - advantages
- Habits
- Interests
- Social status
- Daily schedule (is the character busy during the days, or have more flexible days?)
- Motivations
- Personality

After done with the analysis the groups began the task of designing a touchscreen infotainment system for their character. To concretise the task there were basic requirements that each group’s system had to include:

- Music (change, play, stop, pause)
- Radio (set frequency)
- Navigation (enter address)
- Telephone (answer, hang up)
- Volume
- Open / Close / Switch application

Results

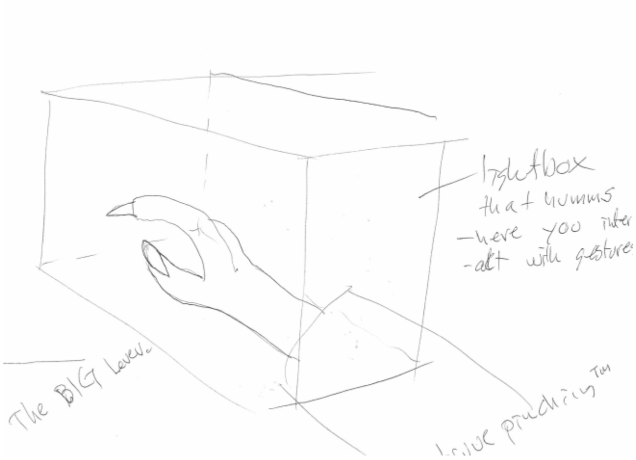
The three different characters yielded three different versions of the infotainment system based on the groups' analysis of their character. What follows here is a short presentation of each character based on these analyses:

Yoda

Yoda is a Jedi Master, around 800 years old, who can use the force to control objects. He is considered to be a kind, old, wise man that is not very tech savvy and likes things to be old school. He can read minds which can cause social problems for him but he is considered to be a good guy who people like and trust. Yoda lives for his purpose to keep their world a safe place.

When Yoda is interacting with the world he uses his three-finger-hands to do gestures to control things through his mind. What also should be noted is that Yoda talks with skewed word order.

Yoda controls his infotainment system completely by using gestures. Voice recognition was ruled out because of Yoda's way of talking. These gestures are performed in a light box. See figure to the right, placed in the vehicle, which is a space designated to recognise gestures performed inside. The light box gives a humming sound as feedback to Yoda when he puts his hand inside to interact.



Concept drawing of a light box for Yoda

Winnie the Pooh

Winnie the Pooh is a friendly bear with a childish, almost naive, and careless approach to life. He lives without prestige and is an involuntary leader among his friends. He lives in the moment and his biggest interest in life is honey ("hunny"), of which he consumes a lot, making him slightly overweight. He is considered to be stupid, but he is also an advisor to his friends, giving them his simple wisdom

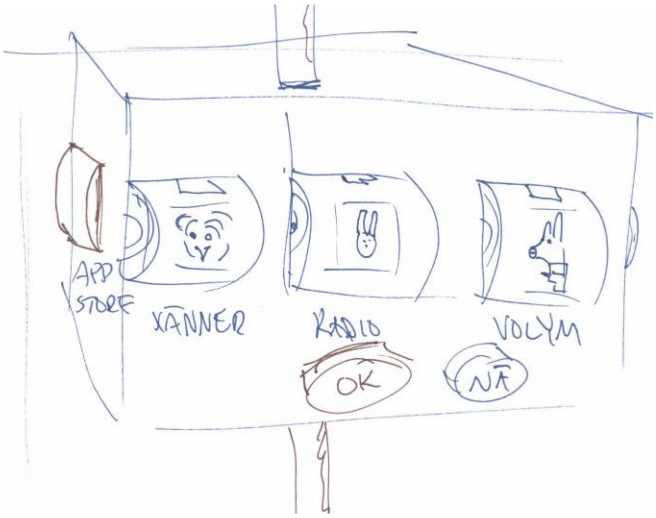
Ideation for Winnie the Pooh

about life. Winnie the Pooh is also an unscheduled guy, who does not make plans, and is easily distracted from what he is doing.

Winnie the Pooh’s interaction principles are direct and intuitive interaction. It cannot be too complicated gestures, since he have no fingers, only thumbs. The system should not provide many options to Winnie the Pooh because then he will not be able to decide.

Winnie the Pooh has a system which focuses on his spontaneous approach to life and aims to act as one of Pooh’s friends. Upon start, the system prompts Winnie the Pooh with questions about different functions that can be activated. The system may ask Pooh whether he would like to visit Piglet or not. These questions are asked repeatedly until he has confirmed a place to go to. Time wise, this might be more time consuming, but Winnie the Pooh does not care, but rather appreciate the given suggestions of what to do.

The system also relies on simple interactions and alternatives since Winnie the Pooh is easily distracted and considered somewhat stupid. The system also have a box with spinners, similar to slot machine, se figure to the right, which Winnie the Pooh can use to control the infotainment system, including navigating to friends, radio channels and volume. The box also has two selection buttons, one for “yes” and one for “no”. These symbolise the few alternatives Winnie the Pooh must have to be able to make a decision.



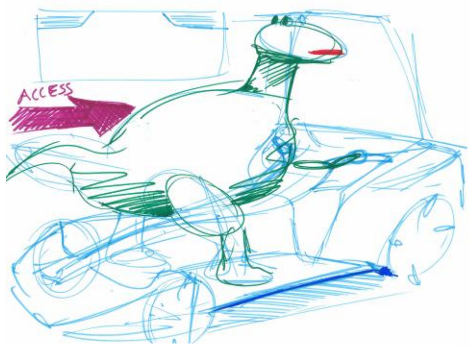
Concept drawing for Winnie the Pooh

Rex

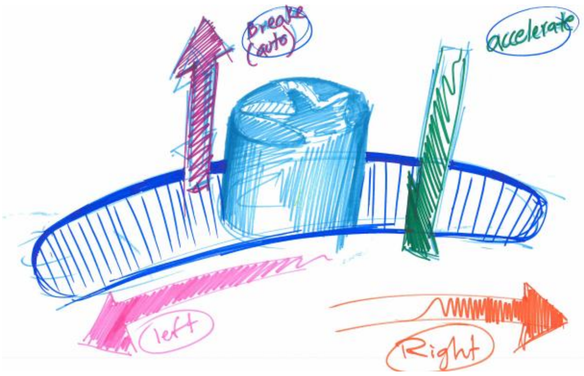
Rex is an easily scared dinosaur who is very loyal to his friends. He is not considered to be very smart and he has a short attention span. He is a follower and acts similar to a puppy. Rex’s motivation is to please his friends, hence he is very friendly.

A physical trait is Rex’s very short arms, which significantly are limiting his reach. In addition to this he only has three fingers with no opposing thumbs, making it hard for him to grip or grab things. His large head is also a problem for Rex, since it makes it hard for him to look down without tilting his whole head. This is also the reason why he cannot see his hands.

Rex is having his infotainment system as a heads-up display (HUD) projected on the windshield. This is to compensate for his lack of ability to see downwards. Coupled to this the vehicle’s interior is completely redesigned, see figure to the right. The new design is



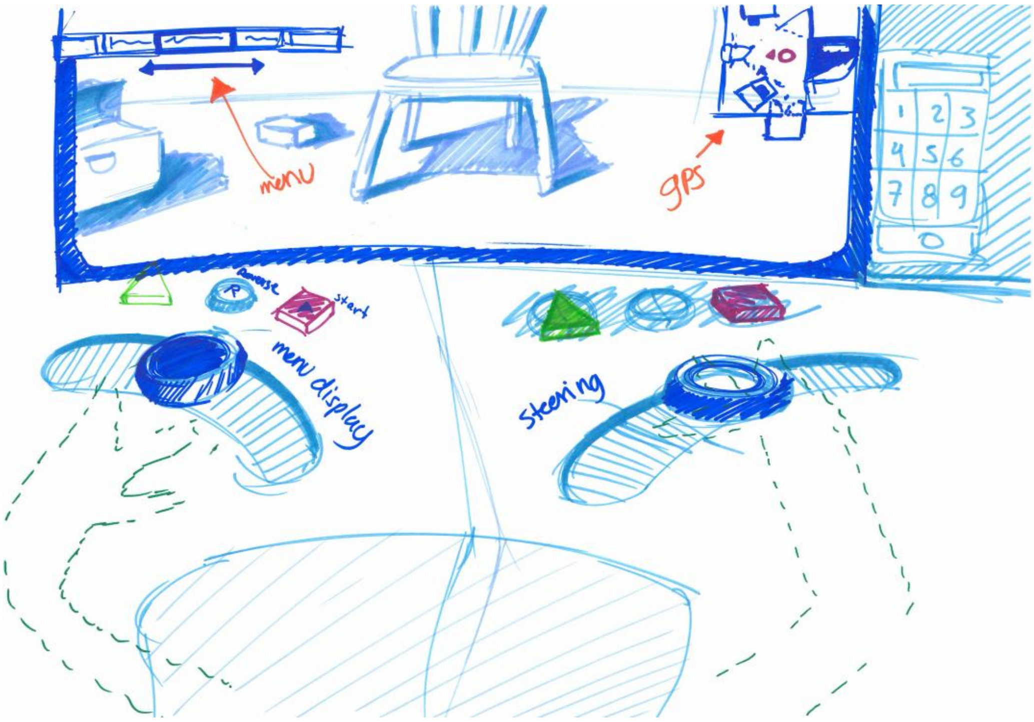
Concept for a redesigned interior



Concept of redesigned steering

higher and allows Rex to come up closer to the windshield, thus reaching even with his short arms. The new design enables steering with only one hand, see figure to the left, freeing the other to control the infotainment system. Because Rex cannot see his hands the design incorporates physical buttons for him to interact with the system, see figure below.

The HUD has a hierarchical menu system where Rex can slide the controller to navigate through the different menus and choices.



Concept drawing of Rex's infotainment system

Analysis

One first thing which can be noted when it comes to the group's general approach to designing infotainment system. For them it was hard to imagine a system completely without physical buttons. Even though the participants were considered to be relatively tech savvy they had a hard time to envision how touch technology could enhance the experience and the effectively compared to physical buttons and traditional in vehicle controls.

All of the groups discussed the possibility of using voice command system and some also incorporated this somewhat into their design. Many of the participants considered a voice command system suitable for controlling the infotainment system. However, during the workshop the participants' experiences with such systems were discussed. Most of them were not satisfied with these systems explaining how hard it is to be understood correctly by the system. Some of the participants also stated how these types of systems made them feeling silly while using them. The conclusion here is that even though a infotainment system can be controlled by voice commands, the controls of the system must have redundancy and not rely solely on voice interaction.

In general many of the groups' concepts incorporated multimodal interactions, combining gestures, voice, physical buttons and touch in different ways. The concept for Yoda involved free form gestures as the way of interacting, which can be a powerful tool, the biggest problem is to map the gestures intuitively to the controls according to most people, not only to Yoda. Of course, some controls are easier to map than others, for example the volume can be increased by a raising hand or by pointing a thumb upwards. Still even in this, relatively simple, example there are many ways to map the control while keeping it rather intuitive. In addition in the concept for Yoda, the box indicating where to perform the gestures seems like a good idea to give guidance of where the gestures should be performed, in what area the system can interpret gestures.

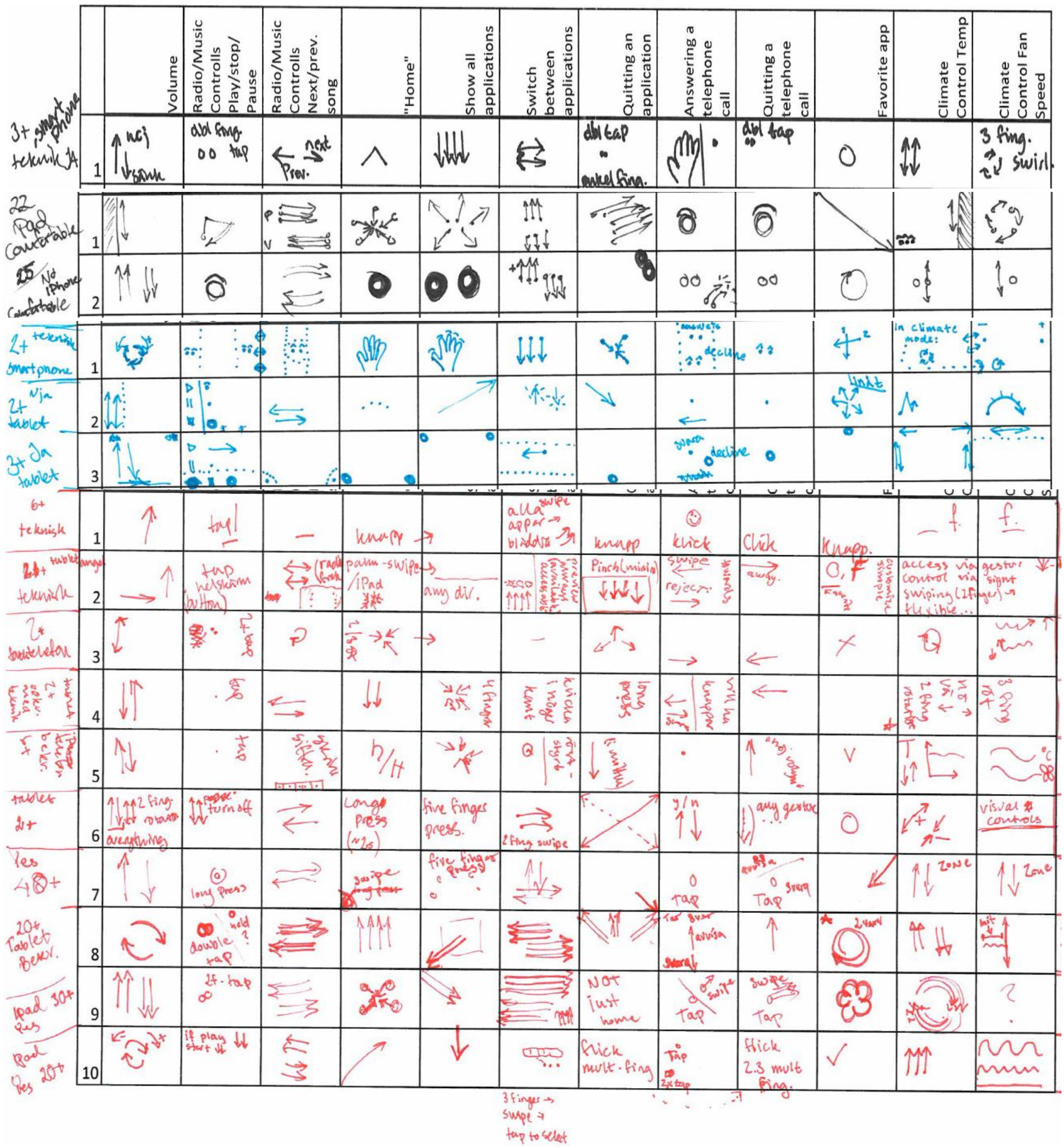
The case of Rex who is having hard time seeing his arms can also be applied to humans when driving a vehicle. During driving the driver is visually occupied with the task of driving, and making an interface which can be controlled without looking seems desirable. The groups solved the problem by using a HUD to be projected in the windshield, but one could also consider using some variation of screen reader providing the driver with feed forward, a concept where the user gets feedback before an action is performed, to reduce the need of actually looking at the screen.

Further in the case of Rex, the design highlights the issue of reaching for the screen versus having a device placed closer to the body, enabling interaction easier at hand.

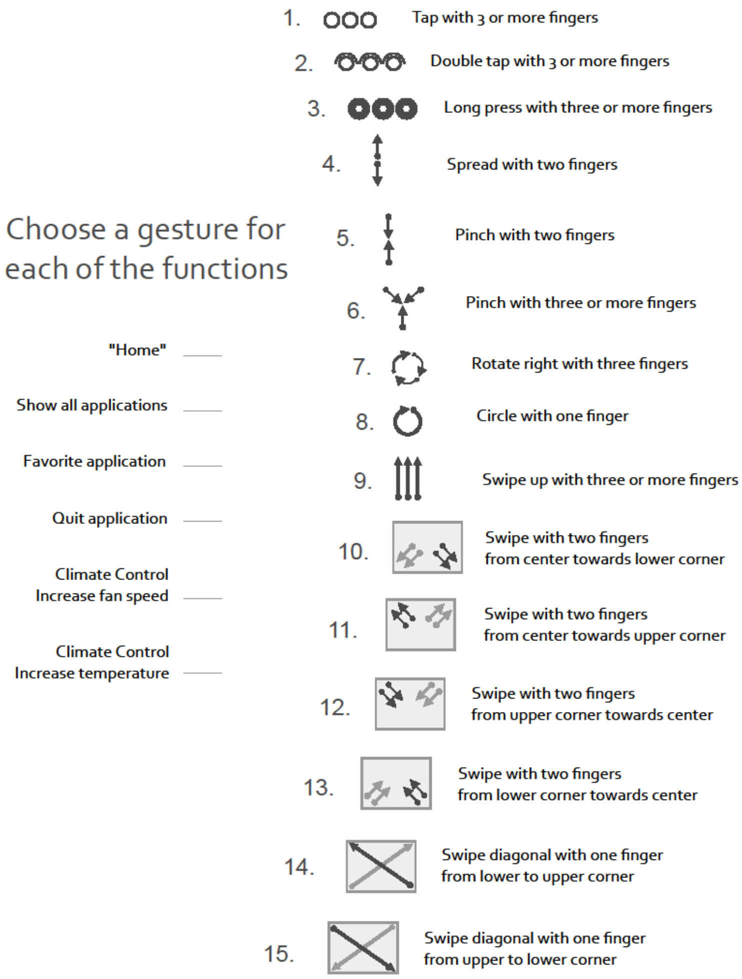
Winnie the Pooh's interface symbolises the simplicity which is required when designing infotainment systems. The task should not be unnecessarily complicated, neither interaction-wise nor decision-wise, especially not while the car is moving.

Appendix VII GESTURE MAPPING

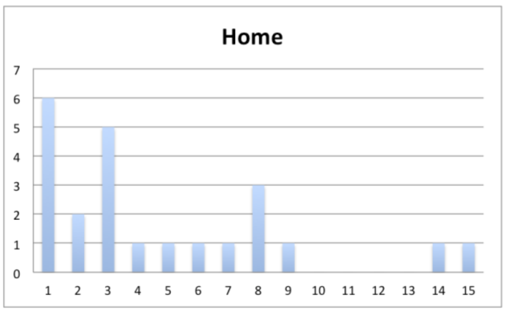
User data from the first iteration, 16 participants, 22-63 years old.

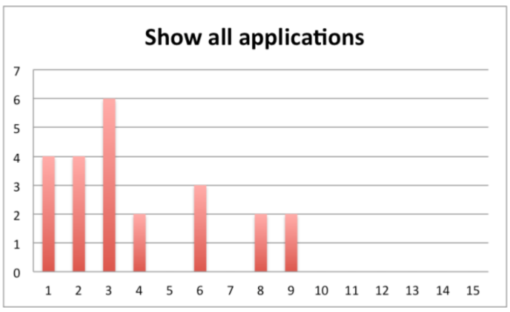


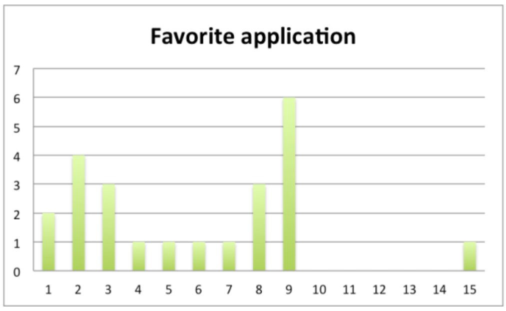
Form used during the second iteration. 23 participants, 23-61 years old.

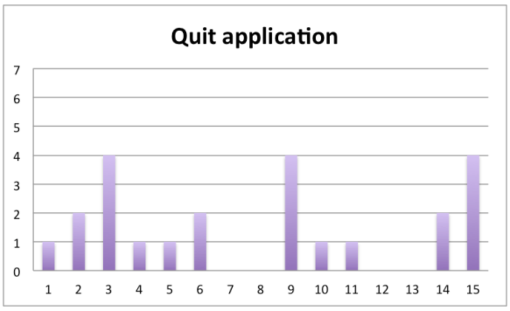


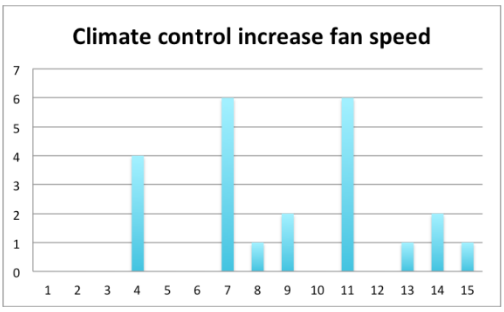
Diagrams for the second iteration having the gesture number on the X-axis and the number of participants choosing the specific action on the Y-axis.

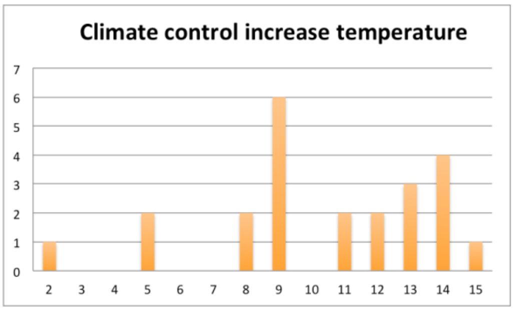












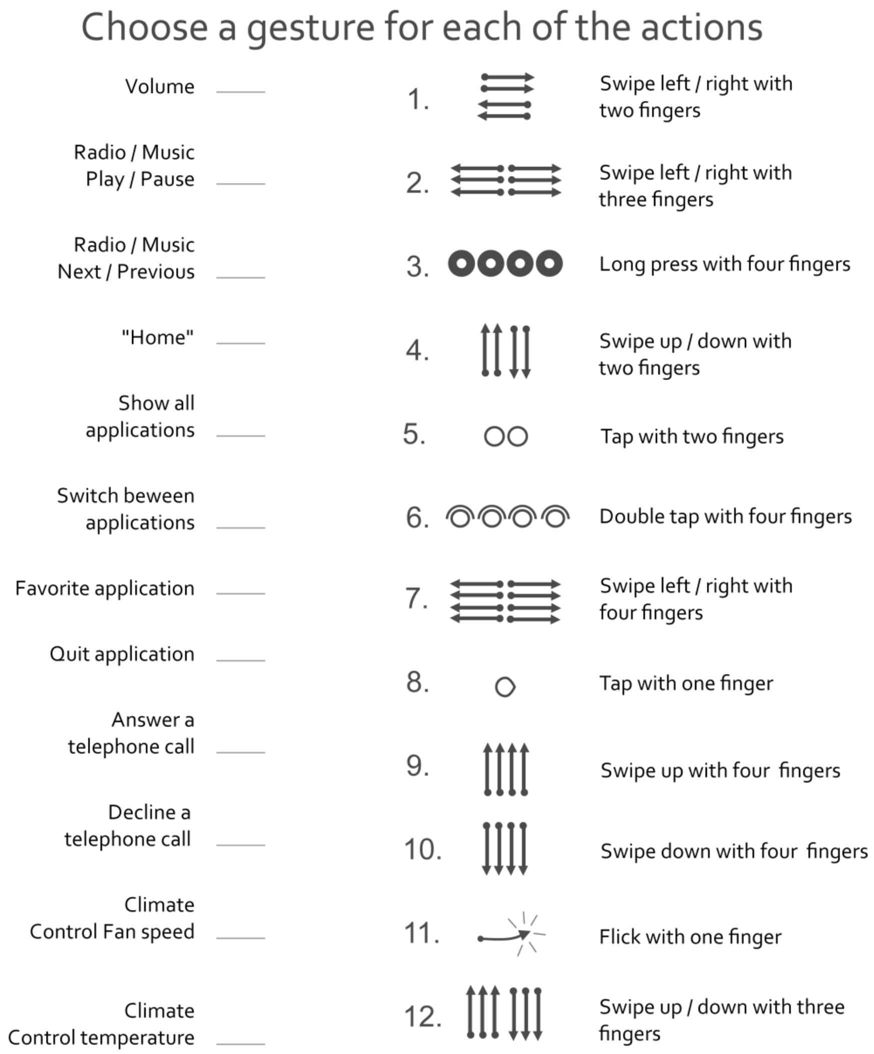
Forms for the third iteration of gesture mapping.In total 27 participants, 14 participants testing the Users' concept and 13 participants testing the Designers' concept

Users' Concept

Choose a gesture for each of the actions

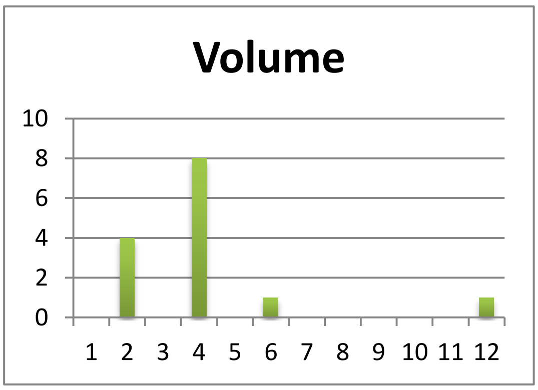
Action		No.	Gesture
Volume	___	1.	Swipe left / right with two fingers
Radio / Music Play / Pause	___	2.	Rotate right with three fingers
Radio / Music Next / Previous	___	3.	Tap with three or more fingers
"Home"	___	4.	Swipe up / down with two fingers
Show all applications	___	5.	Tap with two fingers
Switch beween applications	___	6.	Circle with one finger
Favorite application	___	7.	Swipe left / right with three or more fingers
Quit application	___	8.	Tap with one finger
Answer a telephone call	___	9.	Long press with three or more fingers
Decline a telephone call	___	10.	Swipe diagonal with one finger from upper to lower corner
Climate Control fan speed	___	11.	Flick with one finger
Climate Control temperature	___	12.	Swipe up with three or more fingers

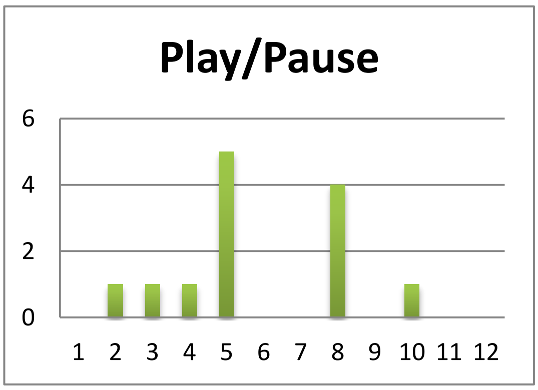
Designers' Concept

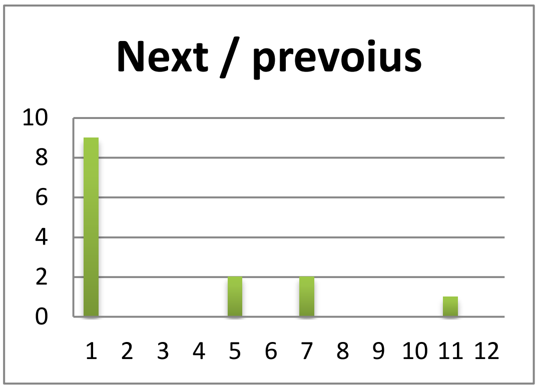


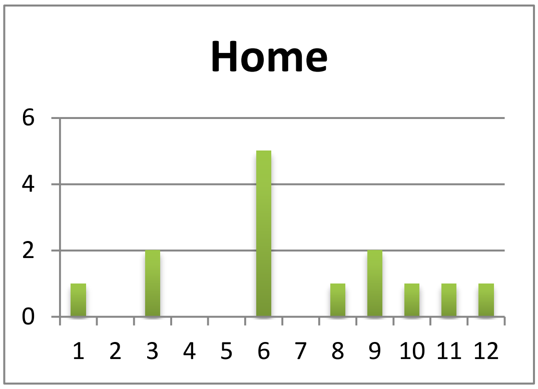
Diagrams for the third iteration having the gesture number on the X-axis and the number of participants choosing the specific action on the Y-axis.

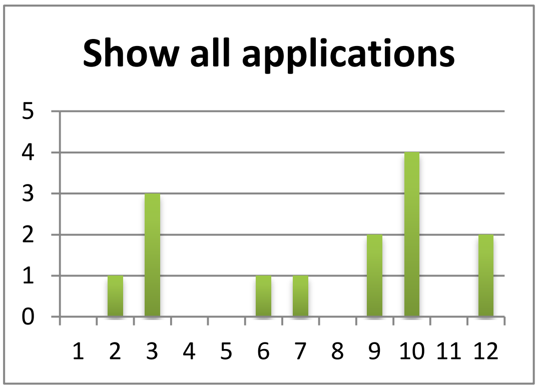
Users' Concept

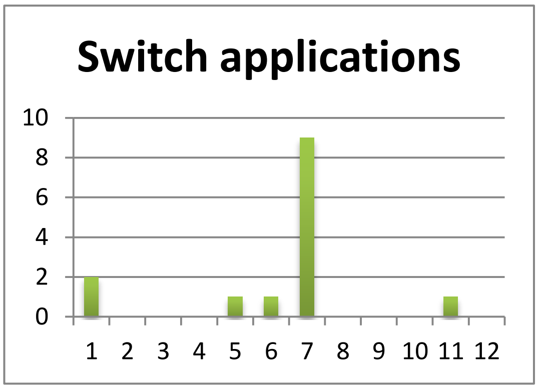


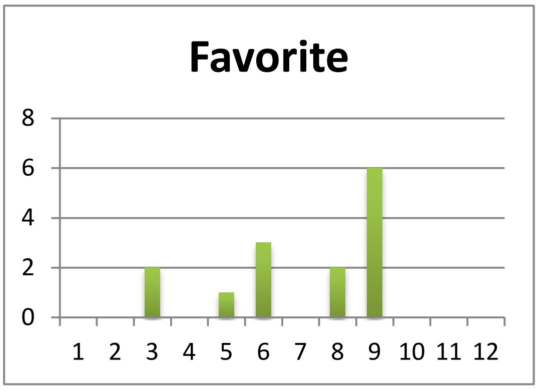


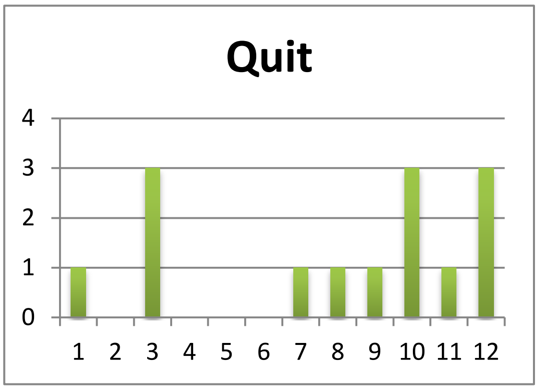

Next / prevoius
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12

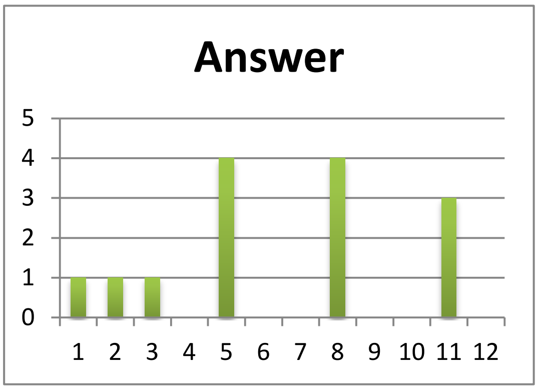

Home
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12

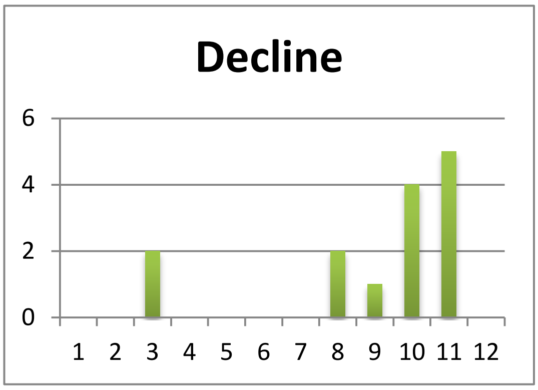

Show all applications
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12

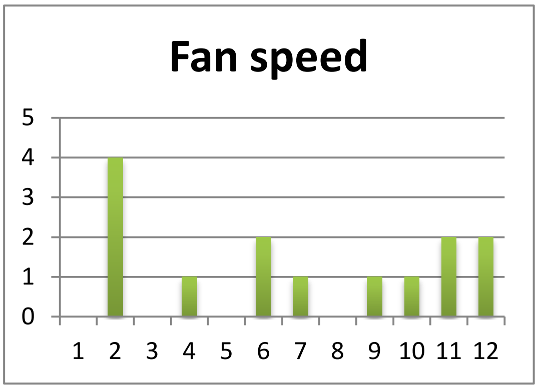

Switch applications
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12

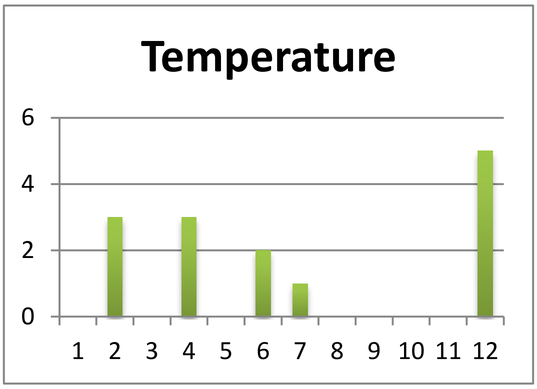

Favorite
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12


Quit
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12

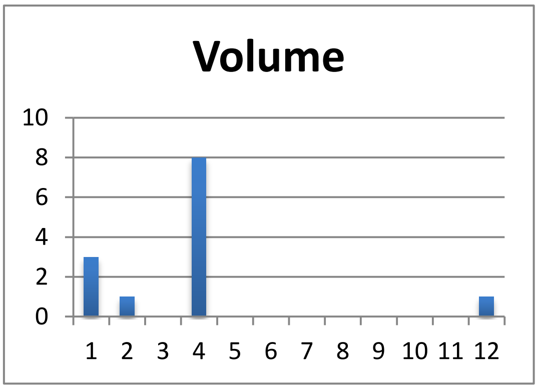

Answer
5
4
3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12

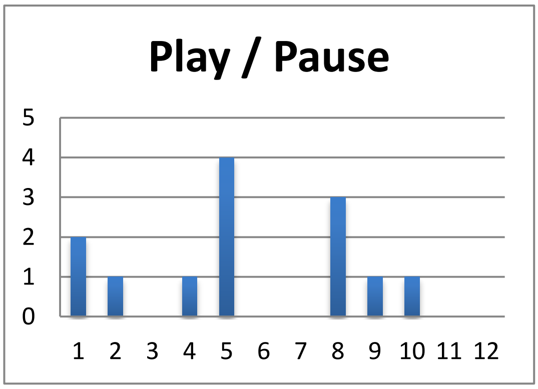

Decline
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12

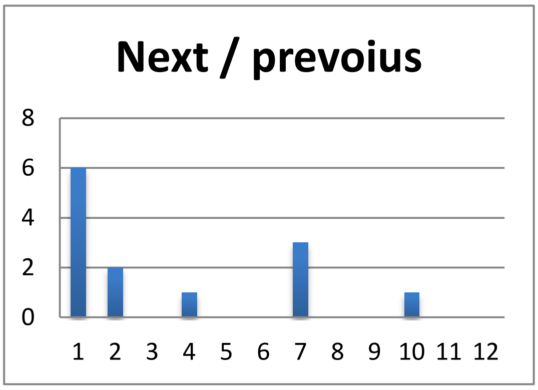


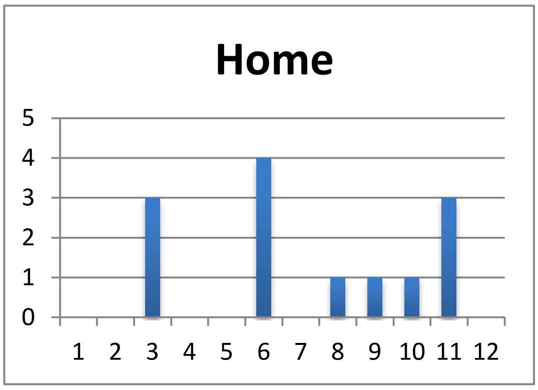


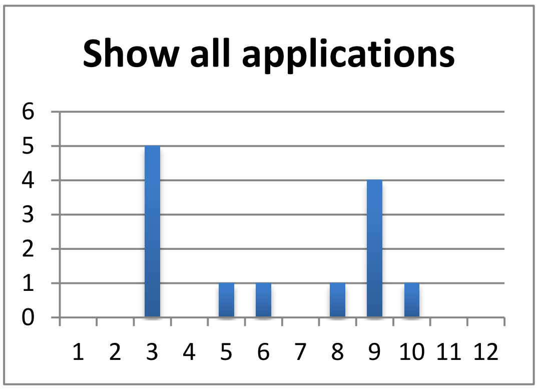
Designers' Concept

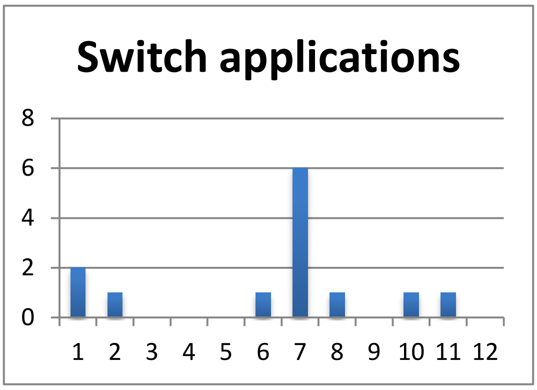


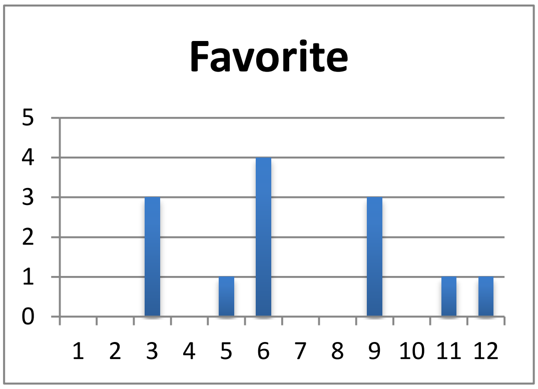


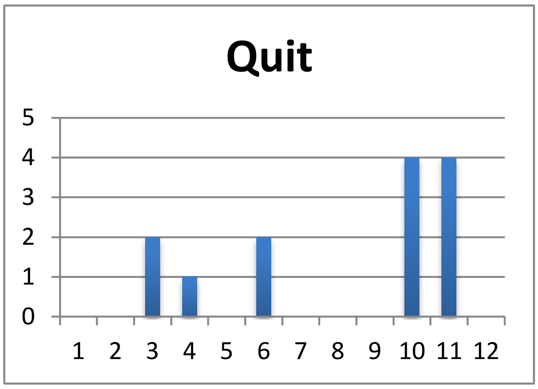


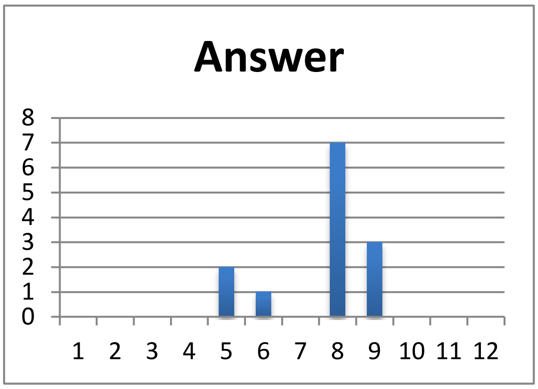


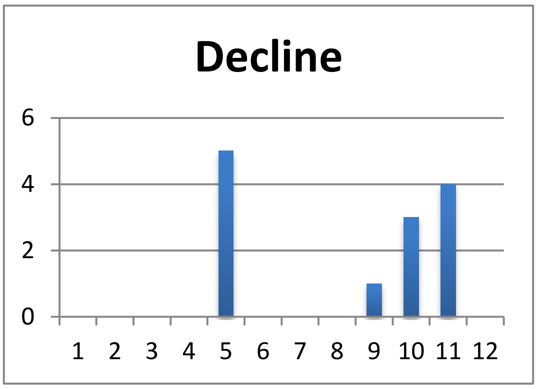


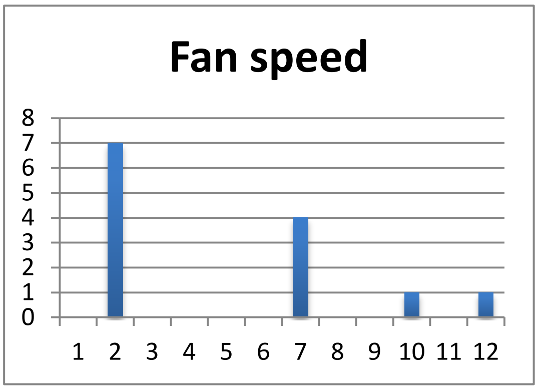


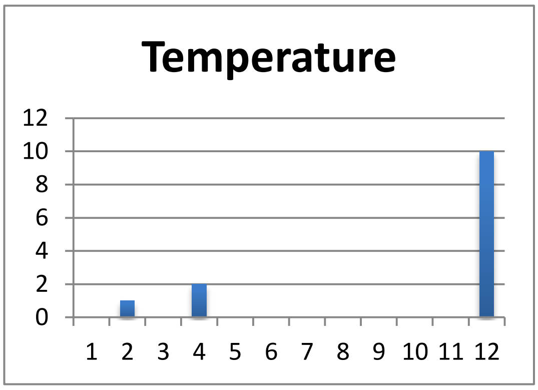

Favorite
0 1 2 3 4 5
1 2 3 4 5 6 7 8 9 10 11 12


Quit
0 1 2 3 4 5
1 2 3 4 5 6 7 8 9 10 11 12


Answer
0 1 2 3 4 5 6 7 8
1 2 3 4 5 6 7 8 9 10 11 12


Decline
0 2 4 6
1 2 3 4 5 6 7 8 9 10 11 12


Fan speed
0 1 2 3 4 5 6 7 8
1 2 3 4 5 6 7 8 9 10 11 12


Temperature
0 2 4 6 8 10 12
1 2 3 4 5 6 7 8 9 10 11 12

Appendix VIII EVALUATION OF FINAL PROTOTYPE

Use scenario

1 Start music
2 Adjust volume until comfortable
3 Enter an application
4 Set temperature on ⅓ and fan speed on .
5 Switch to phone app
6 Decline the phone call
7 Go "home"
8 Open all applications
9 Go to favorite application
10 Go to previous track
11 Close application

NASA-TLX data

Results from driving normally (in Swedish).

Summering

Standard

Här summeras dina betyg tillsammans med viktningar, vilket summeras till ett totalbetyg.

Faktor	Betyg	Poäng	Viktning
Mental	2	5	0.33
Fysisk	2	1	0.07
Tidspress	2	2	0.13
Egen prestation	1	4	0.27
Ansträngning	2	3	0.20
Frustration	1	0	0.00
Slutlig poäng	28.89 %		

Summering

Standard

Här summeras dina betyg tillsammans med viktningar, vilket summeras till ett totalbetyg.

Faktor	Betyg	Poäng	Viktning
Mental	2	5	0.33
Fysisk	2	1	0.07
Tidspress	2	2	0.13
Egen prestation	1	4	0.27
Ansträngning	2	3	0.20
Frustration	1	0	0.00
Slutlig poäng	28.89 %		

Summering

Standard

Här summeras dina betyg tillsammans med viktningar, vilket summeras till ett totalbetyg.

Faktor	Betyg	Poäng	Viktning
Mental	3	5	0.33
Fysisk	1	1	0.07
Tidspress	1	0	0.00
Egen prestation	4	4	0.27
Ansträngning	3	2	0.13
Frustration	2	3	0.20
Slutlig poäng	48.89 %		

Summering

Standard

Här summeras dina betyg tillsammans med viktningar, vilket summeras till ett totalbetyg.

Faktor	Betyg	Poäng	Viktning
Mental	2	4	0.27
Fysisk	1	0	0.00
Tidspress	1	1	0.07
Egen prestation	1	5	0.33
Ansträngning	1	3	0.20
Frustration	1	2	0.13
Slutlig poäng	21.11 %		

Summering

Standard

Här summeras dina betyg tillsammans med viktningar, vilket summeras till ett totalbetyg.

Faktor	Betyg	Poäng	Viktning
Mental	1	3	0.20
Fysisk	1	2	0.13
Tidspress	1	2	0.13
Egen prestation	1	5	0.33
Ansträngning	1	3	0.20
Frustration	1	0	0.00
Slutlig poäng	16.67 %		

Summering

Standard

Här summeras dina betyg tillsammans med viktningar, vilket summeras till ett totalbetyg.

Faktor	Betyg	Poäng	Viktning
Mental	1	4	0.27
Fysisk	1	2	0.13
Tidspress	1	1	0.07
Egen prestation	1	5	0.33
Ansträngning	1	3	0.20
Frustration	1	0	0.00
Slutlig poäng	16.67 %		

Summering

Här summeras dina betyg tillsammans med viktningar, vilket summeras till ett totalbetyg.

Faktor	Betyg	Poäng	Viktning
Mental	2	3	0.20
Fysisk	1	1	0.07
Tidspress	1	4	0.27
Egen prestation	1	0	0.00
Ansträngning	1	2	0.13
Frustration	1	5	0.33
Slutlig poäng	20.00 %		

Driving while interacting with GABI (in Swedish).

Summering

tlx

Här summeras dina betyg tillsammans med viktningar, vilket summeras till ett totalbetyg.

Faktor	Betyg	Poäng	Viktning
Mental	3	2	0.13
Fysisk	2	0	0.00
Tidspress	2	3	0.20
Egen prestation	3	4	0.27
Ansträngning	2	4	0.27
Frustration	3	2	0.13
Slutlig poäng	42.22 %		

Summering

gesture+driving

Här summeras dina betyg tillsammans med viktningar, vilket summeras till ett totalbetyg.

Faktor	Betyg	Poäng	Viktning
Mental	4	5	0.33
Fysisk	2	0	0.00
Tidspress	3	2	0.13
Egen prestation	3	4	0.27
Ansträngning	3	3	0.20
Frustration	3	1	0.07
Slutlig poäng	55.56 %		

Summering

gesture+driving

Här summeras dina betyg tillsammans med viktningar, vilket summeras till ett totalbetyg.

Faktor	Betyg	Poäng	Viktning
Mental	4	5	0.33
Fysisk	1	0	0.00
Tidspress	2	2	0.13
Egen prestation	5	4	0.27
Ansträngning	3	1	0.07
Frustration	2	3	0.20
Slutlig poäng	58.89 %		

Summering

gesture+driving

Här summeras dina betyg tillsammans med viktningar, vilket summeras till ett totalbetyg.

Faktor	Betyg	Poäng	Viktning
Mental	3	5	0.33
Fysisk	2	1	0.07
Tidspress	2	1	0.07
Egen prestation	4	4	0.27
Ansträngning	4	3	0.20
Frustration	2	1	0.07
Slutlig poäng	54.44 %		

Summering

gesture+driving

Här summeras dina betyg tillsammans med viktningar, vilket summeras till ett totalbetyg.

Faktor	Betyg	Poäng	Viktning
Mental	2	4	0.27
Fysisk	1	0	0.00
Tidspress	2	1	0.07
Egen prestation	1	4	0.27
Ansträngning	1	2	0.13
Frustration	2	4	0.27
Slutlig poäng	26.67 %		

Summering

gesture+driving

Här summeras dina betyg tillsammans med viktningar, vilket summeras till ett totalbetyg.

Faktor	Betyg	Poäng	Viktning
Mental	3	4	0.27
Fysisk	1	0	0.00
Tidspress	2	4	0.27
Egen prestation	3	4	0.27
Ansträngning	3	2	0.13
Frustration	2	1	0.07
Slutlig poäng	44.44 %		

Summering

gesture+driving

Här summeras dina betyg tillsammans med viktningar, vilket summeras till ett totalbetyg.

Faktor	Betyg	Poäng	Viktning
Mental	4	3	0.20
Fysisk	1	0	0.00
Tidspress	2	1	0.07
Egen prestation	3	5	0.33
Ansträngning	4	2	0.13
Frustration	2	4	0.27
Slutlig poäng	50.00 %		

Interview Questions

1. How often do you drive a car?

   Not often, a few times a year.

   Before when having a car, I drove more. Not so much anymore.

   Not often.

   Frequent driver.

   Frequent driver.

   Before when having a car, I drove more. Now I drive sometimes.

   Not often.

2. How is the system to use when driving?

   Felt good after some practice, good to have underlying logic.

   Good.

   Cool, it felt good, hard to separate between all the gestures.

   Good,

   Unusual, good.

   Good, especially the fan and music feels natural. It was hard to interact with 4 finger.

   Quite OK, the screen did not always react.

3. Is this something that you would like to have in your car?

   Yes.

   Absolutely!

   Yes.

   Parts: music and telephone, the rest is too complex gestures

   Yes, perhaps other placement

   Yes, the volume and the temperature is something that can be used quickly.

   Yes.

4. Would you use it?

   Yes.

Yes.

Yes.

Perhaps, might be a question of getting used.

Yes.

Yes.

Yes.

5. What advantages can you find?

It doesn´t have to take your attention when interacting.

No buttons, no distractions.

When getting used to the system you can interact without having to search for the buttons, trial and error is possible, can be extended with software.

The gestures can be used everywhere.

Completely learning the system would mean more focus on the driving task.

It is good to have cross-platform gestures when driving a new car, no button to be pushed simply a big area to use.

Big areas where to interact, looks visually nice, easier to upgrade, not as static as ordinary systems, easier to keep up to date, with practice less distraction.

6. Disadvantages?

Some complex gestures.

The fan gives to physical feedback, would be nice with for example bound feedback as well.

Learning curve.

The gestures are hidden functionality; impossible to find through physically searching, no “Panic-button” to shut system (sound) off.

The learning of the system.

Frustrating if the gesture is not remembered, have to restrict the available apps to fit the context.

Perhaps this screen was too big?, might utilize more screens to interact with.

7. Learning the system?

    Felt good.

    Quite easy, logical.

    Intuitive, conformed to existing conventions.

    Easy when not in car, harder to remember in car, but it would probably get better with more practice.

    Felt good.

    Hard with mapping of the four fingers gestures, the rest have a more natural mapping, feels more intuitive.

8. Strange gesture?

    Double-tap with four fingers.

    The directions when changing song: it felt logical when inside but when outside it felt wrong. I tried to mimic the arrows.

    Better visual feedback when changing the music, visual feedback is covered by hand when interactiong, visual feedback when changing temperature could be to change the color of the whole screen (red/blue).

    Four fingers, hard to know if inside the screen (on the iPad) or not, Favorite, Home, all apps. Close, hard to keep track of them all.

    Music: swipe left to right would mean previous song. [cmp. Draw an arrow]

    Four finger gestures were hard.

    Four finger longpress, and double-tap felt strange, the visual feedback when changing climate settings were obscured by the hand, a better placement could perhaps be close to the gear stick to avoid reaching for the screen.