SmartHUD

Allan Aabern

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Aalborg University
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1 Introduction

The driver's task today quite differs from what it was 100 years ago. Back then, and in the absence of automated systems, most of a drivers' mental workload involved controlling the vehicle. After liberating the driver from constant adjustments while travelling, there are new problems arising. According to Hole [1], there is a tendency to think that car driving is a waste of time that could be better spent on other activities. As a consequence, cars are becoming filled with devices for information exchange.

Experts predict that computers will become increasingly important for drivers at all levels, and the technological innovations will lead to increasing automation. According to Walker, Stanton and Young, cited by Hole, [1] the goal will be to ensure that these technological innovations can be used easily, safely and enjoyably. From a psychological point of view designers will have to ensure, that drivers have an appropriate mental model of how their car operates and how it will respond to their actions. Mental models are the user's conception of how a system operates and how it will respond to actions. It is built from direct knowledge and previous experiences, but they can often be incomplete, inaccurate and unscientific. Problems arise when the user's mental model differs from the system designer's mental model. That's why system designers need to take into account how drivers are likely to apply existing mental models to new technologies.

Mostly cars are warm, quiet, smooth and contain comfortable furniture. Future technologies could therefore increase problems of driver tiredness by giving the driver less to do. They could even reduce the drivers' information-processing workload to a point that leads drivers into a dangerous state of "underload" which could exacerbate sleepiness [1]. For future cars, designers should thus concentrate not on minimizing the demands of the driver, but on ensuring that the driver is functioning at an optimum level with attentional resources, at a level high enough to cope with the demands while driving.

2 Motivation

This report is made in collaboration with an international project called POLE ConSenses, working with a task handed out by the company Continental[1]. The study includes collaboration with five other team members in an intercultural and inter disciplinary POLE study group, which have been a part of an ideation process in Guadalajara, Mexico. The task handed out by Continental was: "*Safer interaction between the driver and her/his car by using all 5 senses in a meaningful way! [2]"* The ideation process in Guadalajara was based on this task and went through a two-phased brainstorming, with a chosen focus on enhancing organization of the daily life while driving. During this process a hypotheses was made; many people use their phone while driving in order to work, write e-mails, check their calendar or engage in related activities.

[1] Company that develops technologies for vehicles

Furthermore, it was decided that the final concept, being developed through this project, should integrate the smartphone as an important part of the system. As such, an initial problem statement was created:

How is it possible to organize our daily lives in a safer way while driving, by reducing the visual workload and using a certain combination of the human senses?

After deciding on this initial problem statement, the project went through different stages to decide on a final concept. These stages will be elaborated in the Pre-Analysis. Following, the research for the final concept is presented.

3 Pre-Analysis

In this chapter the design process for deciding the final concept idea will be presented. Furthermore, related work in areas concerning the final concept will be researched, as well as some research into safety concerning driving and secondary tasks.

3.1 Design Process

In order to test the hypothesis about many people use their phone, while driving, in order to work etc., as well as to support the ideation process of the concepts, a questionnaire was distributed. Furthermore, the questionnaire helped create the requirements for the initial concepts and decide on which features the systems should have. This questionnaire was distributed on Facebook[2] and received 68 responses. The questionnaire can be seen in Appendix at the end of the report.

3.1.1 Questionnaire

The respondents consisted of an almost even distribution of genders, with 54% males and 46% females, and with 95% aged 35 or less. 55% was aged 26 or less, which makes the findings relevant for ideation of a concept aimed at younger drivers. Furthermore, the respondents consisted of 54% Europeans, 33% Mexicans and 13% other, thus making the answers relevant to a concept that can be used in different cultures, European and Mexican etc. See Figure 1 for and overview of countries represented in the questionnaire.

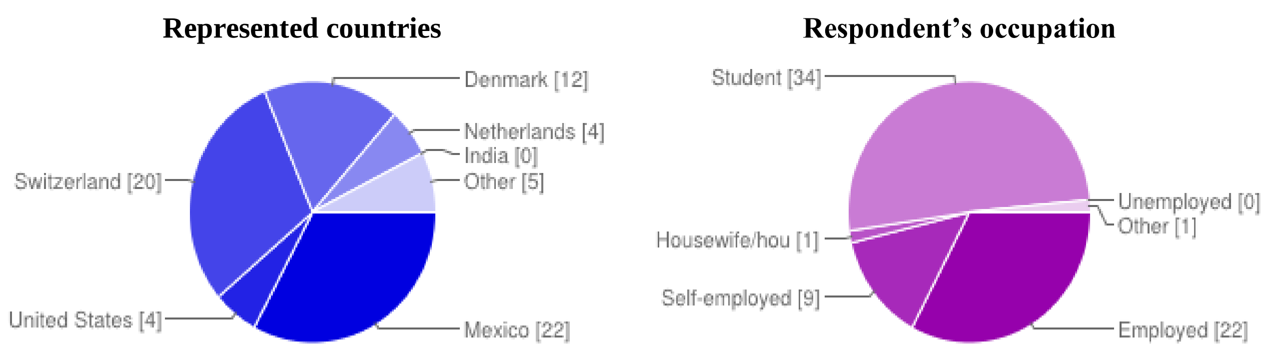


Figure 1: Represented countries: Numbers showing frequency of answers. Respondent's occupation: Numbers showing frequency of answers.

The respondent's occupations were divided as seen in Figure 1, with 51% being students and 33% being employed, thus answers can be used to develop a product for both students and employed people.

As 91% of respondents own a smartphone, it can be assumed that the amount of people not using a smartphone is quite low. This finding supports the idea of creating a system utilizing smartphones, at least focusing on students and employed people.

[2] Facebook: Online socal media

As the product is focused on being implemented in a car, it is needed to be carefully considered if the product should be retrofit able, as well as able to be moved from car to car. The questionnaire showed that 93% drive a car, but 52% own their own car, which suggests that a system should be able to be used in different cars, and not only the users own car.

When asking how often the phone is used while driving, 16% say they never user their phone, 7% use it every time they are driving, whereas 45% only use their phone while driving if it is urgent. See Figure 2 for responses on phone use while driving. However, some interesting findings are made when looking at the results for the question about phone use while the car is standing still, at a traffic light or traffic jam etc. Here only 4% say they never use the phone, and 16% use it every time the car is standing still. These results are almost mirrored from the results about phone use while driving.

These findings, which are supported by Hole [1], suggests that some drivers don't see it as driving when the car is standing still, which is wrong. Drivers tend to use their phone more when the car is at a halt (traffic light, traffic jam etc.). Also, drivers tend to use their phone especially when a call or a text message is "urgent". Which could support the idea of showing short status notifications of e-mail etc. in order to prevent the use of the phone if it is not urgent, and making it easier to be up to date while driving.

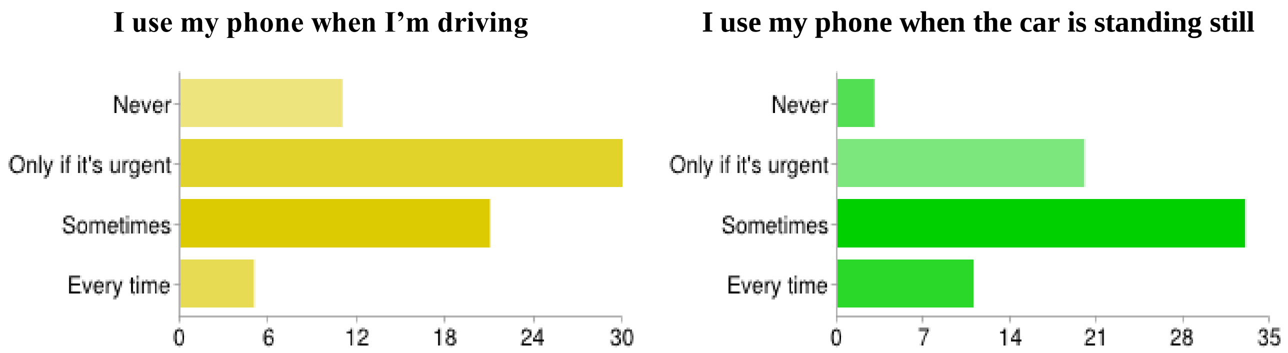
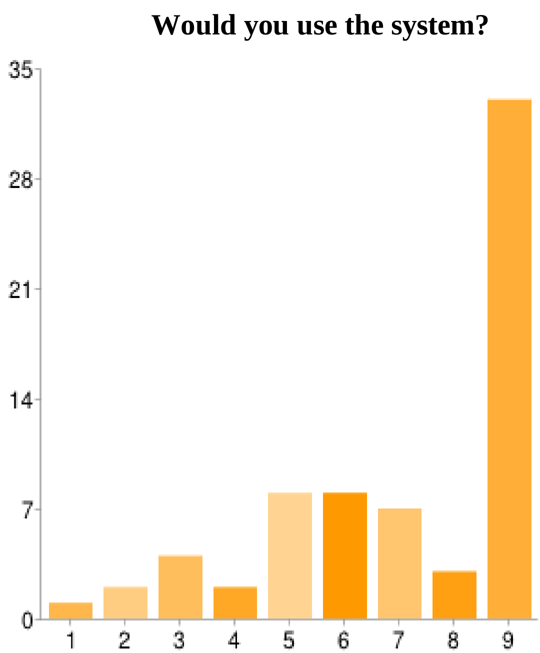


Figure 2: Phone use while driving (left), and when car is standing still (right). Ordinate axis showing answer, abscissa axis showing frequency of answers

The main usage of the phone while driving is calls (20%), SMS (18%), navigation systems (13%), internet (9%), music (9%), Social networks (8%), and e-mail (8%). Thus, calls and text messages should be available to do in the system at some point, since the answers suggest that drivers will use these features no matter what. Also, navigation systems are being used quite frequently, which could be combined with the check list somehow. It also shows that text messages are more important than e-mails, for some at least. Social networks are shown to be not as important as assumed.



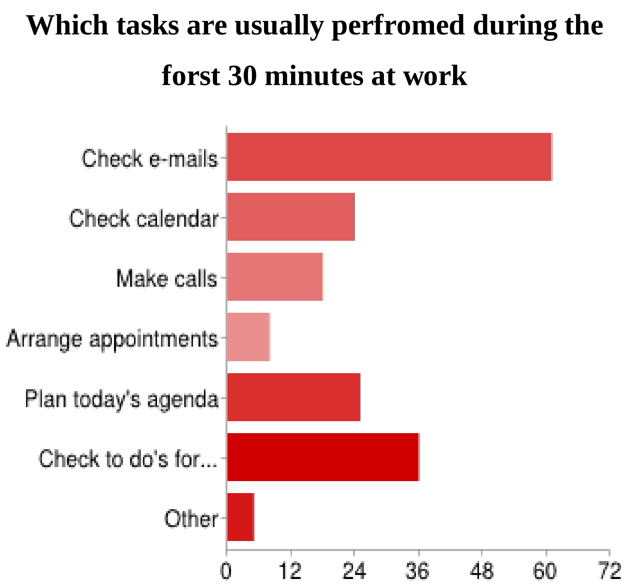


Figure 3: (Left) Graph showing frequency of respondents who wants to use the system, on a scale from 1-9, where 1 is not at all, and 9 is definitely. Ordinate axis showing frequency of answers, Abscissa axis showing rating. (Right) Graph showing tasks performed during the first 30 minutes at work. Ordinate axis showing task. Abscissa axis showing frequency of answers.

In Figure 3 it is shown that a system which makes the driver able to use the phone while driving, and not compromise safety, is wanted by the respondents, as 49% strongly agree that they would use it, and 38% somewhat agree that they would use it. As such, it is found that there is a market for a product that allows the driver to stay "organized" while driving, in a safer way.

The respondents were also required to elaborate on which tasks they performed during the first 30 minutes at work. This question was made to figure out what tasks the driver should be able to do while commuting. 34% check their e-mail, 34% check their to-dos for the day and/or plan the days agenda, while 14% check their calendar. See Figure 3 for responses.

What the respondents were usually thinking about while they are driving, were also asked. This was asked to get input about things that might not have come up during the questionnaire, and to give inspiration of features to implement in the system. Respondents had the possibility to write their answer, instead of having a multiple choice. The answers were then categorized into code numbers 1-7. Each code represented a subject, which can be seen in the table below.

1	Work/school
2	To dos
3	Agenda
4	Private affairs
5	Driving route/traffic
6	Music
7	Other

The frequency of an answer belonging to one of the categories were then calculated, and translated into percentages. The answers given gave an idea of features that could also be implemented in a system for organizing while driving, and could support the other findings in the questionnaire, or give new input. The answers given in textual form can be seen in Figure 4.

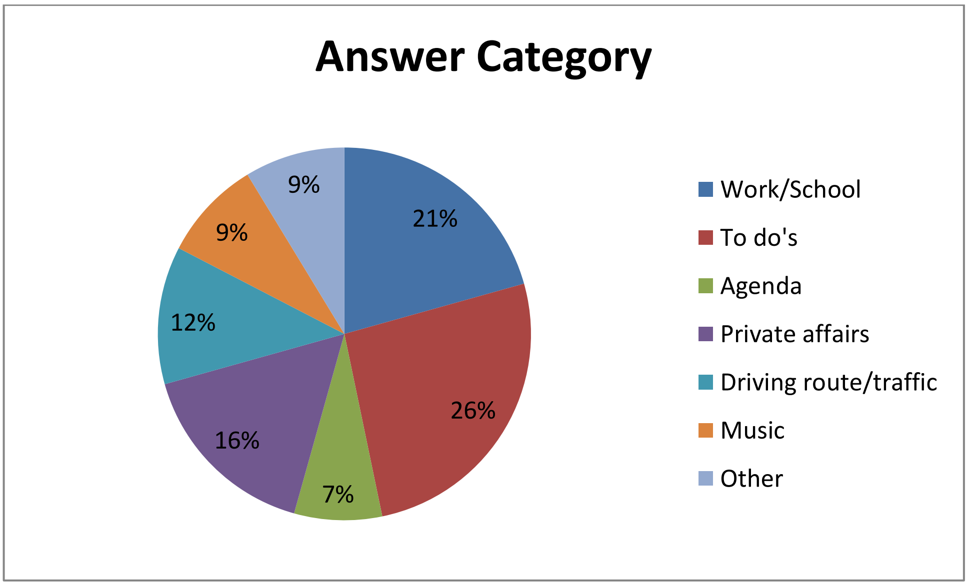


Figure 4: Pie chart showing in percentages the category for answers given in textual form.

The findings in the questionnaire will support the ideation process as well as aid in the process of creating requirements for the concepts. The findings also showed that people do use their phone while driving, to some extent, and that they are thinking about work related things, while driving. Respondents also showed a clear interest in a system that would allow them to use their phone in a safer way, while driving. Thus, the concept of somehow integrating a smartphone in the drivers' environment, in a safer manner, to make the driver able to organize, is reasonable.

3.1.2 Initial Concepts

Based on the ideation process in Guadalajara as well as on the questionnaire, three different possible concepts were created. These concepts were called iD Driver Identity System, Steering Wheel Screen, and Smartphone Projection. One initial sketch for each system can be seen in Figure 5.

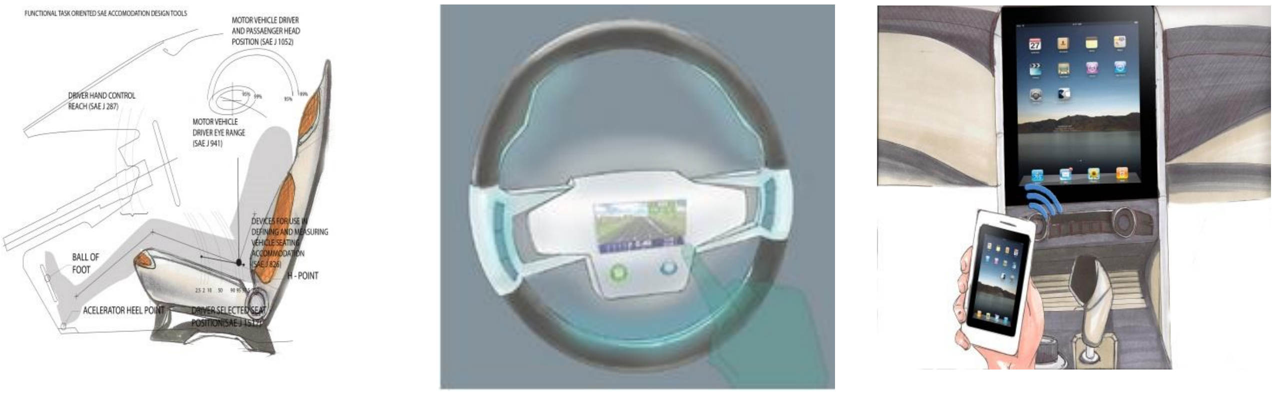


Figure 5: Picture showing an initial sketch, from left to right, for the: iD Driver Identity System, Steering Wheel Screen, and Smartphone Projection.

The iD Driver Identity System is about making the environment the driver sit in, like seat, mirrors etc. adjust automatically to fit the specific drivers' ergonomics. The Steering Wheel Screen is about presenting information in the middle of the steering wheel, to make the driver able to interact with some features of his phone. The Smartphone Projection is about giving the driver the possibility to interact with his smartphone in an easier and less requiring way.

The initial concepts was used in review sessions for the POLE ConSenses project, and based on feedback, as well as discussions in the POLE group, it was decided to focus on the Smartphone Projection concept. As such, research about related work concerning issues with such a system, as well as possible ways to implement it, is done in the following chapter.

3.2 Related Work

As the final concept is about displaying information in a car, ways to do this is investigated. One way of displaying in a car is through a Head-Up Display (HUD).

3.2.1 HUD

When considering HUDs the safety aspect has to be looked into. This has been investigated in multiple papers, where HUDs in most cases were compared to a traditional head-down display (HDD). The experiments in some of these papers concerned safety aids such as visual aid under low visibility conditions [3], effects of a tutoring system using HUD [4], as well as longitudinal and lateral driver assistance [5].

An important aspect of designing HUDs is the question about how much attention demand it requires. The attention demand of a HUD was tested in an experiment made by Liu [6]. The difference on driving performance between drivers’ attention on the HUD and road where investigated using a driving simulator. The four driving scenarios in the experiment concerned attention on the HUD and attention on the road under low and high driving load conditions. The drivers where given goals which were to drive safely, within speed limit, as well as perform a detection task and a speed limit sign response task. While driving the attention on the road scenario, road signs would appear at the right side of the road and the detection task, consisting of diamond shaped markers, would appear at the left and right side of the screen. The driver should then react on the speed limits by either accelerating or decelerating, as well as react to the detection task by activating the left or right turn signal, representing the left or right detection task markers accordingly. In the attention on HUD scenario the same method applied, although the road signs were replaced by presenting the speed limits on the HUD. See Figure 6 for picture of the two different scenarios.

Figure 6: Picture showing the scenario without the HUD (left), and with the HUD (right). [6]

The findings from this experiment showed that when drivers paid attention to the HUD, the response time where decreased compared to the attention on the road scenario. Furthermore, the driving performance showed to be better, when using the HUD. This performance was measured in variance of steering wheel angle.

The study shows that the added load due to the HUD does not inflict any noticeable negative effect on driving, which could imply that a HUD is not a dangerous addition as such. However, the experiment was carried out using a simulator which is vastly different than driving a real car, in a real environment. Furthermore, the content in the HUD used in this experiment is of a low amount, thus if more, or other content is added to the HUD, another attention demand experiment has to be made.

3.2.2 Design of a HUD

When designing a HUD it is also necessary to consider at which distance from the drivers' eyes it should be projected, to avoid issues about re-focusing from HUD to road scene and vice versa as much as possible.

In a study by Charissis and Naef [7] about HUD interface projection distances, they tested three different projection distances, 0.7m, 2.5m, and 5m, as can be seen in Figure 7.

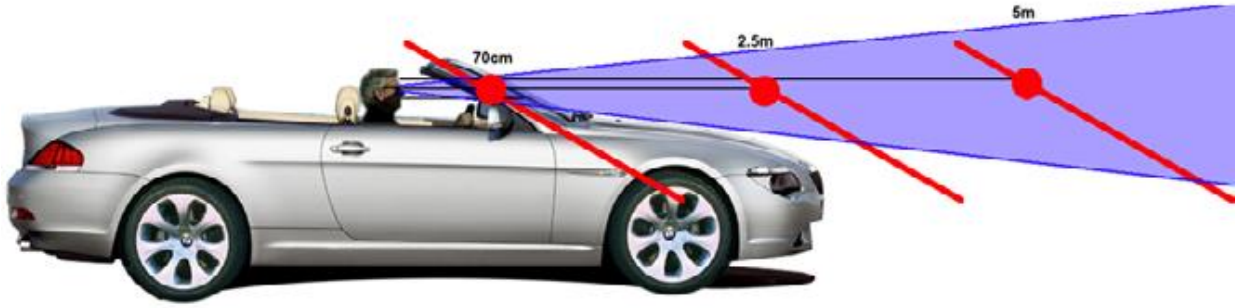


Figure 7: The three different tested distances for the HUD.[7]

In this study, the results showed that a distance of five meters were the most preferred, as it provided a more consistent alignment with the existing physical objects in the road scene. Furthermore, users reported the five meters distance to be the most comfortable distance of the three.

However, another study by Liu [6] found recommendations for projection distance of a HUD to be between 2.4 and 4 meters from the driver, as well as being positioned from 4 to 12 degrees below the driver's horizontal viewing line.

The above suggests that the HUD should be placed at a distance of 2.4 meters or further away from the driver's eyes, in order to reduce the time needed to re-focus from a HUD to the road-scene. The furthest test condition (5 meters) showed to be the most comfortable, and resulted in less time needed to re-focus, thus a distance of 5 meter or further should be considered in the requirements for a HUD. Even farther distances could be considered, as long as the information projected is still easily readable. Such further distances would require testing to conclude if it reduce or increase the time it takes to re-focus, compared to a distance of five meters.

Technologies already used to display information in a car, include the In Vehicle Infotainment systems (IVI). Thus, research on existing IVI systems is presented in the following.

3.2.3 In Vehicle Infotainment

As the problem assessed concerns organizing while driving, it would also be interesting to look into the existing hardware for In Vehicle Infotainment (IVI), as these kind of systems are already used for organizing, making phone calls etc. The state of the art in this area should also help clarifying what is possible to implement today, and maybe give an idea of what could be implemented in the future.

Today smartphones can be used for many things, like checking the calendar, accessing social media, creating check lists and so forth. However, smartphones also have the possibility to be implemented as an IVI. Some examples of smartphone integrations in the car are mentioned in an article by Agrawal [8], who is an analyst on the intersection of local, social and mobile;

- Automatic emergency dialing
  - If the driver gets involved in a traffic accident, the phone would automatically call for help, or even send a text message to specific users. The idea is that by using sensors in the phone, it would be able to detect when an accident has happened. Although, the phone could also communicate with sensors in the car that know if an accident has happened. These could for example be airbag sensors. Some cars today do have an integrated system for automatic emergency dialing [9], but with the solution of using a smartphone the system would be more general.
- Voice-based speakerphone activation for incoming calls
  - Today the user has to find soft buttons for putting the phone on speaker.
- Destination text messages
  - Entering destinations in a navigation system while driving can be hazardous. Instead, a text message with location information could be sent directly to the navigation system, which then should prompt the user to confirm the location.
- “On my way” messages
  - A smart system that can allow someone else to track your location, for example to eliminate a lot of worry and calls and messages about arrival.
- Presence manager
  - Would automatically inform people that you are driving, reducing the amount of messages popping up on e.g. Facebook, such that the driver is not tempted to answer messages that could potentially be very dangerous.
- Voice caller ID
  - A system tells the driver who is calling via voice.
- Car finder
  - The phone knows when the driver leaves the car, and stores the location, making it easier to locate the car, on for example a map on the phone.

The mentioned suggestions are able to be implemented today with the current technology, and some are even implemented, but could be improved [8].

Some new Mercedes cars will have a Facebook application implemented. This application is boiled down to only consist of a small part of the full version of Facebook that is available when using a computer. The idea is to make the driver able to post some pre-defined status updates while driving, as well as having quick access to a list of friends that are nearby, by the use of a knob. It could also be nearby restaurants that friends of the driver have "liked" on Facebook. This solution in Mercedes is using a high-speed wireless internet connection that is part of Mercedes mbrace2 telematics system [10].

Ferraris' infotainment system makes use of Siri, which is an application from Apple, to handle voice commands. This is to make the driver able to keep the eyes on the road, instead of using vision when navigating the IVI. Automakers have been trying to create their own voice command systems, but they are seen as not functioning properly as they often misinterpret the commands, whereas Siri is found to be more precise [11].

Another solution to reduce the visual load when interacting with e-mail is the application 'Text'nDrive'. This application is for use on smartphones, and lets the driver hear the e-mails while driving. The driver can give the command "read e-mails" and the application reads the e-mails aloud. Afterwards, the driver gets the possibility to reply to the e-mail, and can do so by simply talking to the application, which will then convert the speech to text [12].

Furthermore, multiple car specific applications that can be downloaded to the smartphone is made, and the main focus seem to be about reducing the options available on the screen, usually only giving the driver four different options when the phone is in "car-mode". The majority of the applications give the driver the ability to customize which options should be available while driving, but the default options are map, hands-free texting, quick call, and music. Some of these applications also make use of voice commands. [13]

The above findings give an idea of what is able to be implemented in an IVI system today, as well as some areas in which IVI can be improved. The methods used to communicate with the IVI system in cars today are mostly done through either voice control or by using physical interactions such as buttons and knobs. Other hardware that can be used to interact with IVI systems can be ambient light sensors. These sensors can be used for basic gesture recognition, where hand proximity could be counted as a gesture. Furthermore, the front-facing and rear-facing camera on a smartphone could be used. The front-facing camera can i.e. be used to analyze the drivers face, which would make the system able to recognize if the driver is looking at the phone or not. This can for example show the driver available actions when looking, or if not looking, give color based notifications for speed (peripheral vision). The rear-faced camera can be used to analyze the road in front of the car, which can provide an overlay camera feed for situational awareness if the drive is looking at the phone. Also, the rear-facing camera can be used to analyze the scene for traffic lights when the car is at a halt. This could help notify the drive when to get his eyes back on the road, if he is looking at the phone.

When implementing IVI systems in a car, the risk of driver distraction has to be taken into account.

3.2.4 Safety

Distractions while driving can occur in a multitude of different ways, and can be visual, auditory, haptic as well as cognitive. One form of driver distraction is withdrawal of attention, which according to Brown [14] and Green [15] consist of two different types; general/'eyes-off-the-road' and selective/'mind-off-the-road'. Tijerina [16] describes that the general withdrawal of attention can be spotted in degraded vehicle control, as well as degraded object detection and event detection. Driver fatigue is a contributing factor to this, due to eye-lid closure, or in the case of visual inattention, eyes glancing away from the road. Also, secondary tasks that are visual demanding while driving lead to visual distraction, which comprises the potential to cause crashes. A few examples of secondary visual demand tasks are reading detailed maps or long strings of text while driving. Furthermore, manual tasks that require visual guidance, such as entering text on an unfamiliar keyboard, is also visually demanding [15].

The selective withdrawal of attention, or 'mind-off-the-road', is described by Tijerina to be when vehicle control remains mostly unaffected. However, object and event detection is affected due to the drivers' attention to thought, which can be daydreaming or listening to an auditory message. This can lead to *"a selective filtering of information based on expectations rather than the actual situation and to looked-but-did-not-see phenomena [17]".* The 'looked-but-did-not-see' phenomena can be described as if a driver is engaged in secondary tasks, which could be a phone call. The driver looks at a car changing lanes, but does not really see the car, because his mind is elsewhere, due to the phone conversation, thus colliding with the other car.

Tijerina also mention another form of distraction, which is referred to as biomechanical interference [16]. This form of distraction occurs when the drivers' body shifts out of the natural seated position, for example when reaching for something like a mobile phone or leaning away from the natural driving position. One reason why this type of distraction is hazardous is that it reduces the ability to execute maneuvers related to the primary task, driving. This can jeopardize safety for instance when the driver has to avoid an obstacle.

As an example for solutions made, that reduced mechanical effects, such as reaching for a phone while driving, is the hands-free phone. However, this solution cannot reduce the cognitive distraction involved in the conversation itself. Interesting data concerning hand-free phones emerge from some studies cited in [15]:

"

- *The risk of a collision when using a cellular telephone is up to four times higher than when a cellular phone is not used; units that allowed the hands to be free seem to offer no safety advantage over hand-held units.*
- *The risk of a collision increases with frequency of calls.*
- *Crashes involving phone users are more likely to be caused by inattention, unsafe speed, or being on the wrong side of the road, and are much more likely to happen in cities, a location assumed to demand more attention.*
- *Reaction time while using the phone increases 45 percent for non-regular phone users and 60 percent for regular phone users.*
- *Glance data also suggests decreases in attention to the road due to using the phone while driving.*

[17]"

These findings supports that it is not only biomechanical aspects that are safety issues, but also the cognitive inattention, which is seen as still being present even though hands-free solutions are used. This is also supported by Llaneras [18] who states that visual and mechanical distraction can be reduced, not totally removed, but cognitive distraction, which seems to be the most problematic distraction at the moment, is something we are not able to eliminate as people. Our ability to concentrate on more than one thing appears not to improve [18].

Another aspect to think of regarding distraction is what the cause for it can be. Above mentioned concerned mainly visual, mechanical and cognitive distraction, but also frustration can be a distracting factor. Burns and Lansdown [19] mention some issues with internet services provided to the driver. These issues are listed as:

"

- *Drivers will have to wait an uncertain and potentially long time for the information, because loading time will depend on multiple factors, such as the quantity of information, the demands on the provider and the demand on the device loading the information. Yet every second of delay is a risk for distraction and frustration, both with potential negative consequences on safety.*

- *The dynamic and inconsistent nature of internet information in structure and format and the unfamiliar and unpredictable nature of its presentation will inevitably increase the cognitive demands on the driver, which can become excessive and incompatible with driving; moreover, a mouse would be clearly unsuitable for use while driving, and users rarely browse the Web using a keypad or speech recognition.*

[17]"

From the above findings it is seen that it is crucial to consider connection related issues in terms of speed when developing IVI solutions that requires access to the web. Furthermore, information should be presented in a simplified way more suitable for a car interface, such that cognitive workload would not increase too much, when using the interface while driving.

The findings in this chapter illustrate some risks concerning distractions when designing an IVI for cars aimed at conveying information to the driver. The different types of distraction, selective and general withdrawal of attention, biomechanical distraction as well as frustration all have to be taken into consideration when designing. Further analysis of distractions will be looked into in Analysis when a final problem statement has been made.

3.3 Summary

As has been seen in the results from the questionnaire made to support the hypothesis that people use their phone while driving, many people do use their phone while driving, even though they do not think so in some cases, for example when stopping at a red light. Also, the drivers often think about work related things during their drive, which suggest that features used for arranging agenda and such, should be available in a system for organizing the daily life. Furthermore, it was decided, through a design decision phase that the final concept should be a smartphone projection, which means that the screen from the drivers own smartphone should be presented to the driver, in some way, in the car.

Looking at a way to show information to the driver HUDs were investigated. It was found that HUDs are feasible as a way to convey information, as they do not inflict any noticeably negative effect on driving, compared to traditional HDDs. Furthermore, the projection distance of a HUD should be at least 2.4 meters in front of the drivers' eyes, to reduce the time needed to re-focus from the HUD to the road-scene, thus reducing risks of driver inattention and hazardous situations.

When looking into the risks of driver distractions, especially concerning mobile phone use, it is found that no matter what is implemented as an extra feature in a car; the drivers' cognitive workload will increase. However, it was found that in order to limit the increase of cognitive workload, information has to be presented in a simplified way. Also, the biomechanical interference should be limited, and can be done by e.g. removing the need for the driver to reach out for his phone while driving.

3.4 Final Problem Statement

Based on the above research in the Pre-Analysis, the initial problem statement;

"How is it possible to organize our daily lives in a safer way while driving, by reducing the visual workload and using a certain combination of the human senses?"

, can be refined into a final problem statement.

"What is the effect on comfortably use of a smartphone via a Head-Up Display, instead of a traditional smartphone, while driving?"

The next step is to investigate how the driver can interact with the smartphone projection, such that he/she is still in control. Also, research into distraction will be done further, considering dual-task performance; primary (driving) and secondary (smartphone use) tasks. Finally, research into color psychology is done, to investigate considerations concerning colors in the design.

3.5 Success Criteria

In order to be able to answer the final problem statement, the following success criterion has to be fulfilled:

- The results should give an indication of if the smartphone use via a HUD provides positive or negative comfort

According the research done in the Pre-Analysis a hypothesis can be made: "Presenting the information on a HUD will provide a higher comfort on smartphone use, compared to traditional smartphone use, while driving."

4 Analysis

In this part of the report a further analysis into areas concerning the final problem statement will be done. However, definitions of terms in the final problem statement will be presented first. Following, will be a further analysis into distractions, as well as research into sensors and interfaces for cars.

4.1 Definitions

To be able to design and test that the success criterion is met or not, clear definitions of the terms 'comfortably', 'Head-Up Display', 'traditional smartphone', and 'driving' are needed.

4.1.1 Comfortably

According to the English Oxford Dictionary the word comfortable means that a person is "*physically relaxed and free from constrains [20]"*, or *"free from stress or tension [20]"*. Thus, the interface may not stress the driver which can cause frustration, and potentially lead to hazardous situations, as stated by Burns and Lansdown [19].

Furthermore, it is also assumed that people, who have owned a smartphone over a longer period of time, are comfortable using it, meaning they can navigate the interface of it quickly and effectively. This should also be transferred to the smartphone projection, as the projection is merely a mirroring of the users own smartphone. However, the interaction with the smartphone might be different compared to the interaction with the system being implemented for this project.

4.1.2 Head-Up Display

In this project, a HUD is a projection of a display made on the windshield of the car, or a display perceived as being projected further in front of the driver.

4.1.3 Traditional Smartphone

Smartphones are considered as being able to access the internet, write messages, access calendars, make calls etc. just like the features of e.g. the Samsung Galaxy S3 [21], and are considered as being a traditional smartphone in this project.

4.1.4 Driving

Based on the answers given for the questionnaire presented in Pre-Analysis, the term 'driving' is not a clear definition for everyone, as some does not see it as driving when holding still at a traffic light or being in a traffic jam. As such, driving will be defined as when a person is sitting behind the steering wheel, being in some kind of traffic, whether the car is moving or not. It is not considered driving if the car is standing still at a parking lot or similar.

4.2 Distraction

A further look into how a secondary task can interfere with the primary task of driving is done is this chapter, looking into psychological models of dual task performance.

Even though it is often said that driving is a self-paced activity, in the sense that drivers can often control how demanding driving is, it is not the case. While driving, something can happen that demands the driver's immediate and full attention.

For the past 50 years, psychologist have been investigating how well drivers can cope with situations in which they have to perform two tasks simultaneously. As a result, several models of resource allocations have been developed. Most of them are based on the idea that humans have limited cognitive resources to use on any particular task or set of tasks. Performance will deteriorate if the available resources are exceeded by the task demands [1]. It remains rather vague though, what the terms "resources" and "mental effort", used for explaining these models, actually mean in practice. One of the most established theories is Wickens' [22] multiple resource theory. It suggests that there are three dimensions that need to be considered with respect to resources (Figure 8). According to Wickens, dual task performance is affected by:

- the mode of information input (e.g. auditory, visual, tactile)
- the way in which the information is coded (e.g. spatially or verbally)
- the type of responses required (e.g. manual or vocal).

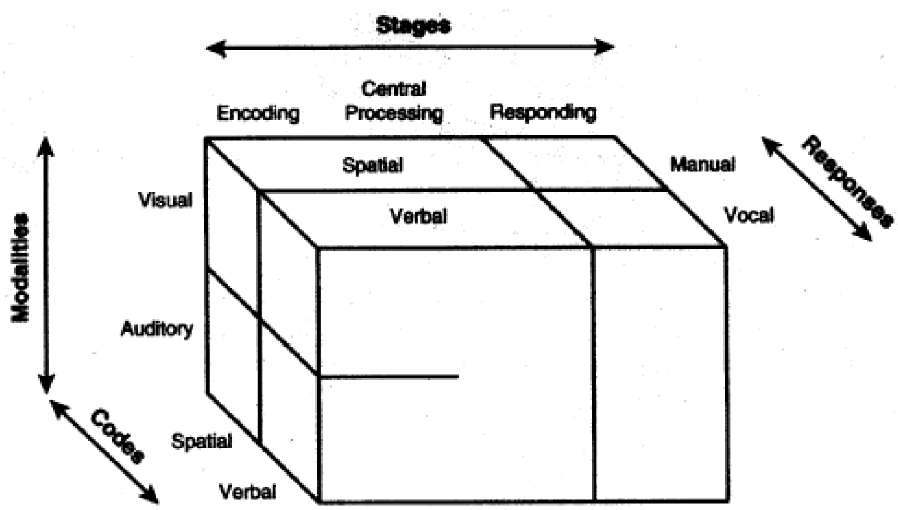


Figure 8: Wickens "multiple resources" model of attention. [22]

If two tasks are similar in terms of their sensory or motor requirements, e.g. two auditory signals like talking on the phone and listening to the radio, interference is more likely to occur. Thus, performance will be impaired.

Rasmussen [23] makes a similar distinction between three levels of human performance:

- skill-based level (processing of automated sensory-motor patterns)
- rule-based level (handling familiar task problems, like fixing a bike)
- knowledge-based level (dealing with new, unfamiliar problems)

Rasmussen suggests that all three levels are operating simultaneously, but control is at *one* of the levels at any given time. It is still not possible to predict which of these levels is likely to be most affected by mobile phone use. However, Hole [1] assumes that the impairment is most probable at the rule-based or even knowledge-based level, since most drivers are experienced and driving poses an automatic process (skill-based level). Since young drivers on the other hand cannot show a lot of driving experience, it has not yet become an automated process for them. Therefore more information has to be processed on the skill-based level while driving, using up even more resources than it does for experienced drivers. This is also supported by Fischer et al. [24]: *"Especially young drivers should not be using units like headsets, because due to their lack of experience, their attention should be entirely bound to the primary task of driving. [24]"* Using up the resources in the different levels can pose effects on safety.

All theories of dual-task performance would predict that the use of mobile phones while driving should have some effect on driving performance and therefore safety. There is now mounting experimental evidence though that phone-use is likely to impair driving. Many of these studies are not without faults, but they all seem to be supporting the fact of impaired driving (e.g. Alm & Nilsson [25]; Lamble et al., [26]).

4.3 Sensors

As the system for smartphone projection will be designed for a car, it is necessary to control when the system turns on and off. This can be done with the use of sensing technology. Thus, some sensing technology for human machine interfaces are researched in this chapter.

4.3.1 Biosensors

Biosensors are capable of reading vital signals from a person. These readings can be achieved by calculating heart rate, skin magnetism changes, and body spasms etc. All these reactions are read by patches and the information received can be a direct transmitter of the user's condition while driving.

Biosensors are the combination of biological sensing elements whit a detector system using a transducer. They are more commonly used in diagnostics, pharmaceutical research, environmental industries and pollution monitoring. *"Biosensors consist of a biological entity that can be an enzyme, antibody, or nucleic acid that interacts with an analyte and produces a signal that is measured electronically.[27]"* Therefore, it can be inferred that each biosensor has a biological component and this acts as a sensor in combination with an electronic component to transduce and detect any signal.

A biosensor, like the above mentioned, can be used to read different vital signals from a driver, to recognize e.g. the drivers' presence and thereby either activate or deactivate the system etc. Some advantages of such biosensors are that most are low cost, have small proportions, and are usually quick and easy to use, as stated by Chauhan, Rai, and Singh [27]: *"The advent of cheap, user-friendly biosensors will revolutionize the practice of healthcare monitoring and enables more in-depth diagnosis on a metabolic basis. [27]"*

Other interesting technology to research, when wanting to control a system including Human Machine Interaction (HMI) is nanotechnology.

4.3.2 Nanotechnology

Yousaf and Ali [28] state that *"Nanotechnology is about to affect almost every field of human life. [28]"* This technology will impact electronics, computers, medicine, materials and manufacturing catalysis, energy and transportation. Nanotechnology will allow products to have a smaller size, lighter weight and also resistance, which is very useful in many industries.

Nano science is the study of applications to different materials on a nanometer scale (10^{-9} meters), and the materials can be classified in different phases such as:

- Single phase solids, including crystalline, amorphous particles and layers, etc.
- Multi-phase solids, including matrix composites, coated particles, etc.
- Multi-phase systems, including colloid, aero gels, ferro fluids, etc.

Another characteristic of Nano materials is that they change their properties when their size is reduced, for instance:

"Copper which is an opaque substance become transparent. Platinum which is an inert material become catalyst. Aluminum which is a stable material turns combustible. Silicon insulators become conductors. [28]"

This technology is providing a rich set of variation to materials, changing their structure and tunable properties. Nano technology can be summed as the creation of useful/functional materials, devices and systems controlled on a nanometer length scale and properties (physical, chemical, biological). These properties can be applied on several products and searching for different results. The application of this technology on e.g. a steering wheel can become a connection between the user and the machine.

Nanotechnology can be applied to polymers, making it possible for a patch the size of a finger print to read a persons' DNA and providing identity compatibility; this could be used to make the car aware of who the person driving is, which can provide security. Also, in case of a dangerous scenario the user can be identified immediately. [28]

The way nanotechnology is able to read specific personal data, is by the reactions from the human body and the capability of the micro reading sensors to receive the information and analyze it.

Nanotechnology can be used to improve display screens on electronic devices etc. This can reduce the power consumption, as well as decrease the weight and thickness on screens. The size of transistors can also be considerably reduced and still provide enough energy for a computer to be used, in e.g. and interface for a car. [28]

4.4 Interface for cars

In this chapter, a way of interacting with the interface in the car is analyzed. As the interface for this project should be intuitive, gestures are looked into instead of e.g. physical buttons and so on. Also, color psychology is researched, to find which colors would be suitable for a HMI design in a car, as it is believed that a wrong choice of colors can lead to negative emotions. This was found to be a potential safety risk in Pre-Analysis.

4.4.1 Gestures

The complexity of device handling is constantly increasing through the addition of functionalities into the Human-Machine Interface (HMI) of cars. One approach of simplifying interaction with in-car devices could be to use other human sensory channels [29]. Therefore a lot of research has been done by the automotive industry in order to understand how gesture-control in vehicles could be improved. The gesture-recognition still needs improvement, but with time the technology will improve to a degree which will automatically cause further demand on the market.

One considerable challenge in the development of gesture-control is the fact that gestures differ between cultures. As a consequence, the technology within cars has to be specifically adapted to every country, causing a great deal of additional costs. Also, the system must on one side be able to distinguish between gestures of the driver and the passenger. On the other hand, in order to enable safe driving, it has to recognize if gestures comprise a control-intention or not, and prevent the driver to lose control of the car due to faulty inputs [30].

Zobl et al. divide the gestures into the following [29]:

Referencing (e.g. pointing)	don't have to be learned	
Kinemimic gestures (e.g. beckon)	don't have to be learned	
Symbolic gestures (e.g. pointing for "go")	Have been learned	culture dependent
Mimic gestures (e.g. virtual phone)	Have been learned	culture dependent

As can be seen in the table above, symbolic and mimic gestures seem to be culture dependent, whereas referencing and kinemimic gestures do not have to be learned. According to Zobl et al., there is a limited gesture vocabulary with a high inter- and intraindividual conformity for a variety of applications. Such a gesture vocabulary ideally allows intuitive controlling.

Without further optimization, gesture controlling can lead to visual distraction, but a recent study by Geiger et al. [31] shows significant reduced distraction effects when using gestural user input in comparison to haptic user input. His study also showed, that gesture-control shows positive effects with regard to intuitivity and user acceptance. If the technology is further developed under the consideration of safety aspects, gestural user input proves to be a promising approach to an optimized HMI with regard to multimodal in-car communication.

4.4.2 Colors

Different colors have different effects on emotions [32]. It is therefore necessary to carefully consider the choice of colors used in an interface for cars, as negative emotions might have a negative effect on driving. It was also found in Safety that frustrations can be a distracting factor when driving a car.

According to Frieling [33] colors have three main aspects: brightness, saturation, and warmth. It is stated that warm and bright colors have an activating effect on the human system. They influence the humans in a mentally stimulating way; activate, seem light and mood improving. On the other hand, cold and bright colors have a more calming effect; relaxing and soothing.

In another study by Valdez & Mehrabian [32] effect of color on emotion was investigated. Here findings relating brightness to emotions showed that *"brighter colors (e.g., whites, light greys, or lighter colors) are more pleasant, less arousing, and less domincance-inducing than are the less bright colors (e.g., dark greys, blacks, and darker colors). [32]"*

Findings by Valdez & Mehrabian about darker colors show that they are more *"likely to elicit feelings that are similar to (or weaker variants of) anger, hostility, or aggression. Darker colors are also expected to elicit feeling that constitute components of aggression, anger, or hostility (e.g., displeasure, high arousal, or dominance). [32]"*

The above findings suggest that using brighter colors, instead of darker colors, is a wiser decision, as darker colors are more likely to cause discomfort, which might lead to distraction when driving a car.

A study by Terwogt & Hoeksma [34] investigated preferences of colors, and found that the most liked color is blue, which can be used as guidance for choosing the hue of the color for the system in this project.

4.5 Summary

In this section of the report it was found that dual task performance is affected by the mode of information input, the way in which the information is coded, and the type of responses required. Also, it was found that interference is more likely to occur if two tasks are similar in terms of their sensory or motor requirements, which can impair performance.

It was also found that inexperienced drivers are more likely to use up more resources processing dual tasks, which means when choosing test participants, it has to be taken into consideration if the driver is experienced or not. Studies researched also agreed that phone-use is likely to impair driving.

To register presence of a driver, biosensors can be used. They are usually low cost, as well as quick and easy to use. Nanotechnology is also shown to be of use, as it can considerably reduce power consumption, as well as size and weight. Nanotechnology can also be used to identify a driver, providing security opportunities.

When looking at opportunities for intuitive interactions for the interface, gestures was found to significantly reduce distraction effects compared to haptic user input. Furthermore, gestures were shown to be intuitive as well as having a positive effect regarding user acceptance. Gestures, as a way of interacting, prove to be a promising approach to an optimized HMI with regard to multimodal in-car communication.

The choice of color was also shown to be of great importance, as the use of darker colors is more likely to lead to discomfort. As such, brighter colors should be used in the interface. Also, the color blue was found to be the most preferred, suggesting that this color will be widely accepted in the interface.

5 Design

This chapter will outline how the system should be implemented, as well as why it should be done this way. A look into how the driver should be able to interact with the system is made, as well as how the projection of the smartphone should be done. Also, how the sensors should be implemented is investigated.

5.1 User Interface

When designing an interface for computer information displays, which the concept makes use of in this project, certain considerations about perceptual psychology needs to be taken into consideration. This is to enable the user to get a better understanding of what is presented in an easier way. As such, the Gestalt principles will be taken into account when designing the interface. The Gestalt principles consist of proximity, similarity, closure, area, symmetry, and continuity, as can be seen in the table below [35].

Proximity	Elements near each other tend to be seen as a group
Similarity	Elements that share visual characteristics (shape, color, etc.) tend to be seen as a group
Closure	There is a tendency to organize elements into complete, closed figures
Area	There is a tendency to see group elements in a way that created the smallest possible figure
Symmetry	There is a tendency to see symmetric elements as part of the same figures
Continuity	There is a tendency to group elements into continuous contours or repeating patterns

Also, since the interface is developed for a car, and the fact that the user has to interact with it, while driving, it would be reasonable to consider how much time the user needs to spend navigating the interface. Fitt's law [36] *"propose a formal relationship linking movement time (MT) and the index of difficulty of target selection (ID):*

$$MT = a+b\ ID$$

It statesthat the time it takes a human to move rapidly to a target area is directly related to the index of difficulty for target selection, which is the logarithm of the relation between the movement amplitude (D) and the target effective width (W).

$$ID = log_2\left(\frac{2D}{W}\right)$$

[36]"

By looking at this, it is seen that in order to reduce the time used for navigation between elements on the interface, the elements need to be larger.

5.1.1 User input

In order to make the driver able to interact with the smartphone, while in the car, to e.g. answer calls, write e-mails and texts, and check calendar, an interface has to be implemented. This interface should include elements that are bigger than on the traditional smartphone, according to Fitt's law.

As the concept is concerning a smartphone projection, the interface itself is the same as the users own smartphone. That means that whatever is shown on the traditional smartphone is able to be seen in the new interface in the car as well. The difference is that the elements in the new interface are larger. Also, the way the user interacts with the new interface is different. It was found that gestures was an intuitive and safer way to interact with a system while driving, thus the way that the driver will write text etc. will be done through gestures. An example is the swipe feature on traditional smartphones [37] which is used to type on the keyboard (see Figure 9). This feature can be used in the new interface, such that the driver can simply make the swipe gesture in front of the shown keyboard, without actually touching it.

Figure 9: Picture showing an example of use with the swipe feature. [37]

5.1.2 Color

As was found in the research, the colors used in the interface should be brighter, and not darker. Also, it was found that the most preferred color is blue. Thus, one color used in the interface will be a tint of blue.

To give the interface an option to show the driver different states of specific content, e.g. when a button is pressed, another color is necessary. This color will be the complementary color of the tinted blue color, as this makes the two colors easily distinguishable. The color wheel in Figure 10 shows the two colors, marked with a red dot.

Figure 10: Picture showing a color wheel, where the chosen colors are marked with red dots. [38]

5.2 Smartphone Projection

The concept concerns a projection of the drivers’ smartphone on a HUD, which in this chapter will be discussed how to be done, mainly concerning where to project the smartphone.

During the research it was found that the main issue with HUDs is the time it takes to re-focus from the HUD to the road-scene. The HUD should be projected on the windshield of the car, but the system should also make sure the driver is able to monitor activity outside the car, to maintain situational awareness. Thus, a proposed design is a variable transparency windshield, as seen in Figure 11.

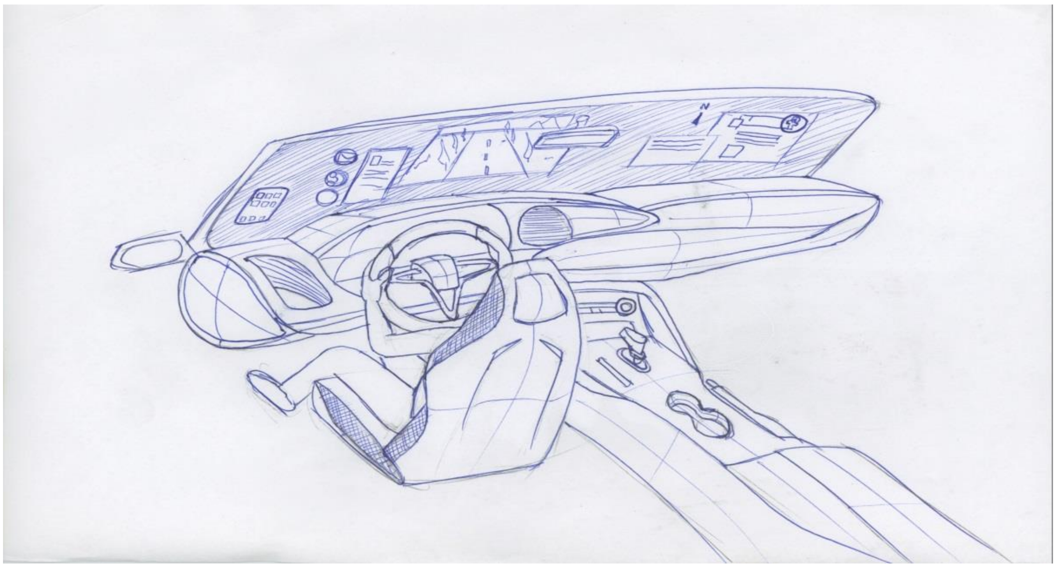


Figure 11: Design proposal for the variable transparency windshield.

The variable transparency windshield is able to turn from completely transparent to almost opaque. When transparent the driver is able to see the road ahead, but when it is almost opaque, the windshield serves as a screen for images to be projected on. By doing this the focal length for both road-scene and HUD are the same and time used for re-focus is eliminated while in opaque mode.

To provide the video feed for the opaque windshield, and external front-facing camera is needed. This enables for the road-scene to be projected on the opaque windshield, and makes sure the driver does not lose track of what is in front of the car, at a focal length the same as the HUD.

To project the drivers' smartphone, existing protocols like MirrorLink [39] could be used.

The place to project the smartphone on the windshield should not be in the direct view of the road-scene. Thus it should be positioned a bit below the drivers' horizontal viewing line, such that it is still possible to see the road ahead of the car.

To ensure that the drivers' hands stay on the steering wheel when looking at the projection, some sensors could be used.

5.3 Sensors

The system needs to be able to recognize if the driver is present, and it was found that in order to make this possible biosensors could be used. As it is a system being developed for a car, it needs to be taken into consideration where it is possible for the driver to activate the system while driving. Multiple options are available, such as the seat, the steering wheel, and the pedals in the car. However, as the system would need to turn on and off, the seat will be disregarded as an option, since the driver is sitting there constantly when driving. The driver also shifts feet positions between the pedals several times, and it is therefore difficult to have a consistent system ‘on time’ without causing very hazardous situations. This is because the driver might suddenly need to brake while using the system, which can cause confusion. However, the driver should always have at least one hand on the steering wheel, and can freely choose where to position his hands on the steering wheel. This makes the steering wheel a good place to position sensors for recognizing the drivers’ presence.

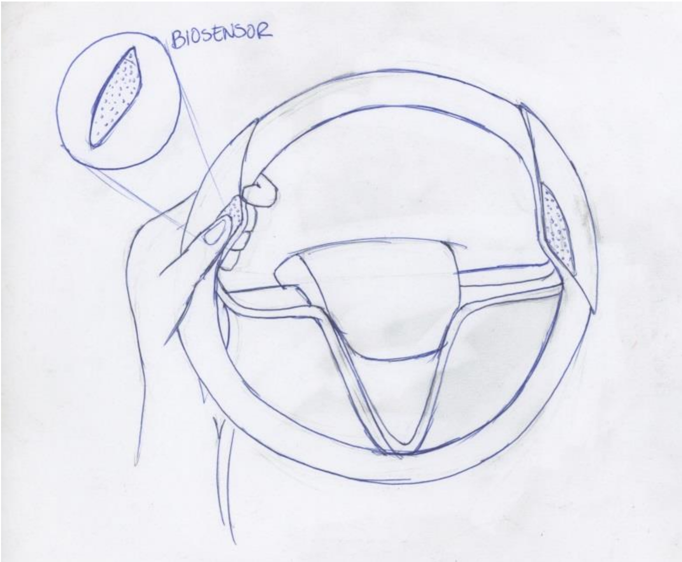


Figure 12: Proposed design for positioning of the sensors.

As the drivers’ hands are on the steering wheel, multiple sensors could be used, e.g. fingerprint-, and heart rate-sensors. Also, the sensors should be positioned where they are easily accessible while driving, and made in a way such that the driver has reduced risk of activating it accidentally. Thus, the sensors should be positioned on the inside of the steering wheel, at the top left and top right, as seen in Figure 12.

6 Implementation

The components used for implementing a prototype of the system are described in this chapter. Also, the implementation is done through two stages, as initial work with sensors is done in Mexico, and final preparations are done in Switzerland.

6.1 Hardware

The sensors used for recognizing the drivers' presence are being attached to a steering wheel, such that the driver can have a thumb on one, or both sensors. Instead of fingerprint readers, force sensitive resistors are used in the prototype. This is able to demonstrate the idea, and can be used to activate the system with a finger present on the sensor. An Arduino Uno is used to manage the signal from the sensors and translate it into a signal that can turn the HUD on and off.

For the HUD a switchable foil is used. This foil can be transparent and change to opaque as well. The foil is transparent when a voltage of 110 is applied to it, as both sides of the foil are covered with a conductive coating, and connected to a conductor rail. The foil consists of liquid crystals that are aligned when electric current is applied to the film, making it transparent, see Figure 13. When the electric current is disconnected, the crystals scatter and the film becomes opaque.

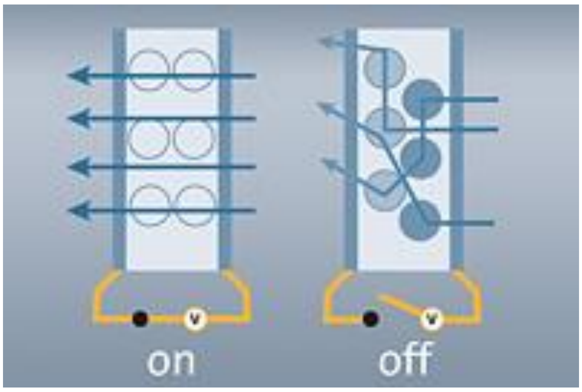


Figure 13: Picture showing the liquid crystals when electric current is on and off. [40]

The foil is then attached to a piece of acrylic glass to mimic a piece of the windshield. Acrylic glass is used instead of real glass for transportation reasons, as real glass has a risk of breaking. Also, acrylic glass is easier to work with and does not cost as much as real glass.

The above mentioned technology with switchable foil is also available as switchable glass [41]. However, this technology is much more expensive, and for a prototype the acrylic glass is found fit for presenting the idea. If a full windshield should have this technology, it could be considered if it should be with the use of the foil or the glass.

The video feed in front of the car can be implemented by using a front facing camera. However, this is not implemented in the prototype, as it will not be implemented in a real car. As such, the road-scene is simulated through a computer, and shown on a screen.

6.2 Interface

To simulate the information on the HUD and windshield a projector will be used. This projector will be connected to a computer which will have a road-scene on it, as well a projection for a smartphone interface, which will be projected onto the HUD area. The projection of the smartphone is only able to be seen when the switchable foil is opaque, which means that the driver will have to keep a finger on one of the phototransistors. When the film is transparent, only the road-scene will be seen. To simulate this, the projection will change to match if the film is opaque or transparent. Meaning the smartphone projection will only occur when the film is opaque.

To project a smartphone an android emulator is used on the computer, which looks and functions exactly as a normal android interface for a smartphone.

Using an emulator also means that the swipe feature proposed in the design is not able to be implemented in the prototype. Also, any interaction with the smartphone projection is not able to be tested in the prototype, as gesture recognition is not implemented. This is due to resource related issues in the project.

7 Experiment Design

The variables used for testing is covered in this section, along with the experiment design structure, test setup and subjects. Furthermore, this section will cover how the experiment will be carried out.

7.1 Variables

As it is not possible to measure how comfortably the test subject can use the interface, due to the gesture controls not being implemented, another aspect of comfort is going to be tested. This other aspect of comfort is the positioning of the HUD as a mean of how accessible it is to interact with if gesture recognition was implemented. Thus, the independent variable in this experiment will be the placement of the HUD.

7.1.1 HUD Placement

It is decided that there will be three different placements; to the left of the steering wheel, as well as in front of and to the right.

The HUD placement may or may not affect the comfort of the system, and the reason for choosing three different placements are that drivers might prefer using right or left hand for using the interface, and the middle placement might show that both right and left handed users can use this comfortably.

The different placements of the HUD will be controlled by having three different video feeds to show the subjects. The three different video feeds are controlled manually by the test conductors.

7.1.2 Comfortably

As ‘comfortably’ is measured in the experiment as what the subjects feel is most comfortable, it is the dependent variable. This dependent variable is being investigated to see whether it will be affected by the independent variable, HUD placement, or not.

It is chosen to keep the answers binary for this experiment, thus providing the subjects to rate the positions as either ‘comfortable’ or ‘not comfortable’. These ratings will be divided into a binary score of 1 and 0, where 1 is ‘comfortable’, and 0 is ‘not comfortable’. The frequency of ‘comfortable’ ratings will be divided by the total amount of ratings for each condition (left, right, middle HUD position), and end up providing a “comfort response rating” (C). This rating will give an idea of what effect the placement of the HUD will have on the comfort level, in this particular concept.

To complement the findings in the experiment, an observation will be made of the subject. This observation is done to see how the subjects will navigate the interface, as well as to see what movements the subjects have to make, in order to do specific tasks.

7.2 Tasks

To be able to test how comfortably the interface is, small tasks will be given to the subjects to complete. The tasks will be the same for each condition, such that they are not a bias. The tasks given will be similar to tasks done on a traditional smartphone.

Tasks chosen for this experiment will be to enter an app, as well as write a short message. Since the interface for the prototype does not allow for any interaction, the subjects are asked to mimic how they would carry out these tasks if the system could recognize gestures.

The short message that has to be written is "I am testing", which is done to see how much effort the subjects need to use. Both tasks will be explained by the experiment conductor, as well as when to do them.

7.3 Experiment Design Structure

The experiment design structure depends on multiple aspects, these being number of subjects, resources available, how many independent variables, and how many different values each independent variable have [42].

The experiment for the concept developed through this report includes one independent variable, and a total number of conditions amounting to three (left, right, middle HUD position). Furthermore, the decision between a within-group design and between-group design has to be made. The within-group design expose all subjects to multiple conditions, while the between-group design expose subjects to only one condition. When choosing one of the group designs, the advantages and limitations of both are taken into consideration. These are listed in Figure 14.

	Type of experiment design	
	Between-group design	**Within-group design**
Advantages	Cleaner Avoids learning effect Better control of confounding factors, such as fatigue	Smaller sample size Effective isolation of individual differences More powerful tests
Limitations	Larger sample size Large impact of individual differences Harder to get statistically significant results	Hard to control learning effect Large impact of fatigue

Figure 14: Table showing advantages and limitations of between-group, and within-group design. [42]

As the learning effect is wanted to be controlled, either a complete counter-balance method, or a random order of showing the position of the stimuli, which is the HUD, needs to be used. It is decided to use a complete counter-balance, as the stimuli only have three different conditions, and with a complete counter-balance it is controlled that each scenarios can be tested the same amount of times. The complete counter-balance method for the experiment will look like shown in the table below.

Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Left	Left	Right	Right	Middle	Middle
Right	Middle	Left	Middle	Right	Left
Middle	Right	Middle	Left	Left	Right

As the experiment consist of three conditions it would probably be harder to get statistically significant results if using a between-group design, whereas a within-group design can provide more powerful tests. Also, the fatigue factor is not assumed to be an issue with only three conditions, which is limiting the time needed for testing a scenario considerably, which can provide options for getting a greater sample size.

As such, a within-group design is chosen, where each test subject goes through all three conditions. Also, a complete counter-balance method is used to reduce the bias of a learning effect, as much as possible.

7.4 Test Set-up

The optimal setup for the experiment is decided in this chapter, and is based mainly on the resources available, as well as the experiment design.

As the experiment concerns an interface for a car, with a HUD displayed on the windshield, the screen used for the projection should be the size of a windshield in a car, which would be at least 50cm x 100cm. Thus, the projector used should project on the whole surface.

The subject will be seated in a silent room to avoid distractions from outside sources. The distance from the seat to the steering wheel, used in the test, will be changeable to make sure that subjects of all sizes can be tested. The steering wheel will be at a fixed position in front of the seat.

In front of the screen that is simulating the windshield, a separate piece of acrylic glass with the switchable foil on will be placed. On this piece, the smartphone interface will be projected upon. The piece of glass can be moved to the sides by the experiment conductors to suit the three different experiment conditions.

The subjects will be told to sit in front of the steering wheel, and adjust the seat to a position they are comfortable with. Then they are told that they will be presented with three different positions of a HUD, where a smartphone is projected on to. They will be told that in order to activate the HUD one or both sensors on the steering wheel need to be activated. Subjects are then told that they cannot interact with the interface, but should imagine that they can control it with gestures, such as using a swipe keyboard, or just point at things they want to click.

After the subjects have been told how the system works, they will be presented with a video feed of a road-scene, as well as a smartphone projection. However, the smartphone projection will only show when at least one of the sensors on the steering wheel is activated. The subject will then be instructed, by the experiment conductor, to carry out the two tasks.

When the two tasks are done, the subject is asked to rate the movements needed to carry out the tasks as either comfortable, or not comfortable. Thereafter, the HUD is changed to a second position, and the tasks and question are the same. Finally, the HUD is changed a second time, with the same tasks and question in the end.

7.5 Subjects

For the purpose of this experiment it is found necessary to have at least 30 test subjects or more. This would mean that for each scenario there are 5 subjects. However, if more than 30 subjects are available, it should be taken into consideration that in order to have the same amount of subjects in each scenario, the total number of subjects is able to be divided by 6, since there are six scenarios.

All subjects should preferably have tried to drive a car and own a smartphone, such that an understanding of driving and smartphone use is present. Furthermore, the subjects should have fully functional body movements, as the experiment concerns comfortable use of an interface, which requires specific gestures.

Optimally an equal amount of males and females, as well as left and right handed subjects, should be tested, to investigate if gender, and left/right hand preferences, has anything to do with the findings. However, it may not be possible to find an equal amount, as the subjects are found using convenience sampling.

8 Discussion

As the prototype for this project is made in Mexico and Switzerland, it is not tested yet. Therefore, a discussion of the test results etc. cannot be done. However, a test will be carried out as a future development, in correlation with the POLE project team in Switzerland, June 2013, such that a conclusion on the final problem statement can be made. The test results will be analyzed, after the data gathering has been done. The data will consist of the comfort response rating (C), as well as observations done through the tests. The test will be done as described in Experiment Design.

The test as well as results, with a discussion and conclusion is to be presented in a complementary paper for this report.

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10 References

[1]. Hole, G. *The Psychology of Driving*, *2007*. Lawrence Erlbaum Associates, Inc., Mahwah, New Jersey. ISBN: 0-8058-4425-2

[2]. Holliger, C. *Pole virtual kick-off*, 2013. Powerpoint

[3]. Charissis, V. & Papanastasiou, S. *Human-machine collaboration through vehicle head up display interface.* Springer- Verlag London Limited 2008. DOI: 10.1007/s10111-008-0117-0.

[4]. Karvonen, H., Kujala, T. & Saariluoma, P. *In-Car Ubiquitous Computing: Driver Tutoring Messages Presented on a Head-Up Display.* Proceedings of the IEEE ITSC 2006. Toronto, Canada 2006.

[5]. Tönnis, M., Lange, C. & Klinker. G. *Visual Longitudinal and Lateral Driving Assistance in the Head-Up Display of Cars.* Mixed and Augmented Reality, 2007. ISMAR 2007. 6th IEEE and ACM International Symposium on, vol., no., pp.91,94, 13-16 Nov. 2007. DOI: 10.1109/ISMAR.2007.4538831

[6]. Liu, Y-C. *Effects of using head-up display in automobile context on attention demand and driving performance.* Department of Industrial Engineering and Management, National Yunlin University of Science and Technology, 2004.

[7]. Charissis, V. & Naef M. *Evaluation of Prototype Automotive Head-Up Display Interface: Testing Driver's Focusing Ability through a VR Simulation.* Proceedings of the 2007 IEEE Intelligent Vehicles Symposium. Istanbul, Turkey, 2007.

[8]. Agrawal, R. *Car and phone integration has a lot of road for improvement*. Article in Venturebeat.com – News, January 2012. Website. Visited: March 22nd 2013. Link: http://venturebeat.com/2012/01/13/car-companies-fail-to-deliver-no-brainer-smartphone-apps/

[9]. *Automatic Emergency Call (eCall).* Euro Ncap. Website. Visited: March 26th 2013. Link: http://www.euroncap.com/rewards/technologies/call.aspx

[10]. Oreskovic, A. *Facebook's newest frontier: inside the car.* Article in Reuters, San Francisco, January 2012. Website. Visited March 22nd 2013. Link: http://www.reuters.com/article/2012/01/09/us-facebook-mercedes-idUSTRE80828C20120109?feedType=RSS&feedName=technologyNews&utm_source=dlvr.it&utm_medium=twitter&dlvrit=56505

[11]. Davies, A. *The $300,000 Ferrari FF Now Comes With Siri And Two iPad Minis.* Article in Business Insider, March 2013. Website. Visited: March 22nd 2013. Link: http://www.businessinsider.com/ferrari-ff-now-with-siri-and-ipad-minis-2013-3?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+businessinsider+(Business+Insider)

[12]. *Text'n Drive.* Website. Visited March 22nd 2013. Link: http://www.textndrive.com/

[13]. Goodwin, A. *Put your phone into 'car mode' with these dashboard apps.* Article in CNET, December 2012. Website. Visited March 22nd 2013. Link: http://reviews.cnet.com/8301-13746_7-57559361-48/put-your-phone-into-car-mode-with-these-dashboard-apps/

[14]. Brown, I. D. *Driver Fatigue.* Human Factors: The Journal of the Human Factors and Ergonomics Society 1994 36: 298. DOI: 10.1177/001872089403600210.

[15]. Green, P. *Crashes Induced by Driver Information Systems and What Can Be Done to Reduce Them.* University of Michigan Transportation Research Institute (UMTRI), 2000. 2000-01-COO8.

[16]. Tijerina, L. *Issues in the Evaluation of Driver Distraction Associated with In-Vehicle Information and Telecommunications Systems.* Transportation Research Center Inc., 2000.

[17]. Chittaro, L. & De Marco, L. *Driver Distraction Caused by Mobile Devices: Studying and Reducing Safety Risks.* 1st Int'l workshop mobile technologies and health: Benefits and risks. 2004.

[18]. Llaneras, R. E. *NHTSA Driver Distraction Internet Forum: Summary and Proceedings.* Driver Distraction Internet Forum, 2000.

[19]. Burns, P. C. & Lansdown, T. C. *E-distraction: the challenges for safe and usable internet services in vehicles*. Internet Forum on the Safety Impact of Driver Distraction When Using In-Vehicle Technologies. 2000.

[20]. *Comfortable.* Definition in Oxford Dictionaries. Website. Visited April 27th 2013. Link http://oxforddictionaries.com/definition/english/comfortable

[21]. *Samsung Galaxy S lll.* Samsung.com. Website. Visited April 27th 2013. Link: *http*://www.samsung.com/global/galaxys3/

[22]. Wickens, C. D. *Processing resources in attention, 1984.* R. Parasuraman & D. R. Davies (Eds.), Varieties of attention (pp. 63-102). New York: Academic Press.

[23]. Rasmussen, J. *Information processing and human-machine interaction. An approach to cognitive engineering, 1986.* New York: North-Holland.

[24]. Fischer, K., et al. *Mobiltelefone am Steuer: Auswirkungen auf das Fahrverhalten bei jungen Autofahrern und Autofahrerinnen* . Fachhichshule Nordwestschweiz, Hochschule für Angewandte Psychologie, Olten. 13DPD3-116158/1.

[25]. Alm, H. & Nilsson, L. *The effects of a mobile telephone task on driver behaviour in a car following situation, 1995.* Accindent Analysis and Prevention 27.5. 707-715.

[26]. Lamble, D., et al. *Cognitive load and detection thresholds in car following situations: safety implications for using mobile (cellular) telephones while driving.* Accident Analysis & Prevention, Volume 31, Issue 6, November 1999, Pages 617-623. ISSN: 0001-4575, 10.1016/S0001-4575 (99) 00018-4.

[27]. Chauha, S., Rai, V., Singh, H. B. *Biosensors.* In Resonance, Volume 9, Issues 12, pp. 33-44. Springer India, 2004. DOI: 10.1007/BF02834305. ISSN: 0971-8044.

[28]. Yousaf, S. A. & Ali, S. *Why Nanoscience and Nanotechnology? What is there for us?* In Journal of Faculty of Engineering & Technology, 2007-2008, pp. 11-20.

[29]. Zobl, M., et al. *A usability study on hand gesture controlled operation of in-car devices.* In Abridged Proceedings, HCI (2001): 5-10.

[30]. *Gestenerkennungs-Technologie vor dem Durchbruch.*Article in Pressetext Nachrichtenagentur, July 2012. Website. Visited: April 21st 2013. Link: http://www.pressetext.com/news/20120713007

[31]. Geiger, M., et al. *Intermodal differences in distraction effects while controlling automotive user interfaces.* In Proceedings Usability Evaluation and Interface Design, HCI (2001): 5-10.

[32]. Valdez, P. & Mehrabian, A. *Effects of Color on Emotions.* In Journal of Experimental Psychology: General, 1994. Volume 123, No. 4, 394-409.

[33]. Frieling, H. *Psychologische Raumgestaltung und Farbdynamik* (2. Auflage). Herausgeber: Institut für Farbenpsychologie Marguartstein/Obb, 1955. Göttingen: Musterschmidt Verlag.

[34]. Terwogt, M. M. & Hoeksma, J. B. *Colors and Emotions: Preferences and Combinations,* 1994. In The Journal of General Psychology, 122(1), 5-17.

[35]. Rosson, M. B., & Carroll, J. M. *Usability engineering: scenario-based development of human-computer interaction*. Morgan Kaufmann, San Francisco, USA, 2002. ISBN: 1-55860-712-9.

[36]. Héctor, A., et al. *Character Activation Time Prediction Model for Tongue-Typing: Adaption of Fitts's Law.* In 31st Annual International Conference of the IEEE EMBS. Minneapolis, Minnesota, USA, September 2-6, 2009.

[37]. *Swype.* Swype.com. Website. Visited: May 3rd 2013. Link: http://www.swype.com/

[38]. *Designer Tips for Working With Color.* Your Decorating Hotline, 2013. Website. Visited: April 27th 2013. Link: http://yourdecoratinghotline.com/helpful-color-tips/

[39]. *MirrorLink.* CarConnectivity Consortium. Website. Visited: April 27th 2013. Link: http://www.mirrorlink.com/

[40]. *MagicFoil-Functionality.* MediaVision. Website. Visited: April 27th 2013. Link: http://www.media-vision.de/en/media-glass-vision/magic-foil/funktionsweise.htm

[41]. *SageGlass.* Sage. Website. Visited: April 27th 2013. Link: http://sageglass.com/sageglass/

[42]. Lazar, L., Feng, J. H., Hochheiser, H. *Research Methods In Human-Computer Interaction.* John Wiley & Sons Ltd., 2010. ISBN: 978-0-470-72337-1.

11 Table of Figures

12 Appendix

Help us make driving more efficient!

We are investigating, how a car could help us organize our daily lives. You can support the development of new technology by taking 5 minutes and answering the following questions. The evaluation is done synonymously of course.

Thank you very much for your help!!!

Do you have a smartphone? *

- Yes
- No

Do you drive a car? *

- Yes, I have my own car
- Yes, I sometimes drive a friend's/family members's car
- Yes, I drive a rental car/make use of car sharing
- I have a driving license but never drive
- No, I don't drive

How much time do you approximately spend in a car per week? *

- Up to 3 hours
- Between 3 and 6 hours
- Between 6 and 9 hours
- Between 9 and 12 hours
- More than 12 hours a week

I use my phone... *

	Never	Only if it's urgent	Sometimes	Every time
...when I'm driving:	○	○	○	○
...when the car is standing still (red light, traffic jam etc.):	○	○	○	○

If you use your phone while driving, what do you use it for? *Multiple options possible.

- ☐ SMS
- ☐ E-mail
- ☐ Calendar
- ☐ Notes
- ☐ Checklists
- ☐ Navigation Systems
- ☐ Internet
- ☐ Calls
- ☐ Social Networks (Facebook etc.)
- ☐ News
- ☐ Music
- ☐ Weather
- ☐ Games
- ☐ I don't use my phone while driving
- ☐ Other:

What are you usually thinking about while you're driving? *For example: Work, things I have to do today, what to cook for dinner, nothing in particular etc.

Which social networks do you use? *Multiple options possible.

- ☐ Facebook
- ☐ Twitter
- ☐ Google+
- ☐ Linkedin
- ☐ Twitter
- ☐ Myspace
- ☐ None
- ☐ Other:

If you could use your phone while driving without endangering your own or other's safety, would you use it? *

	1	2	3	4	5	6	7	8	9	
Not at all	○	○	○	○	○	○	○	○	○	Definitely

What kind of tasks do you usually perform during the first 30 minutes at work? *Multiple options possible.

- ☐ Check e-mails
- ☐ Check calendar
- ☐ Make calls
- ☐ Arrange appointments
- ☐ Plan today's agenda
- ☐ Check to do's for today
- ☐ Other: ______

What's your age? *

- ○ < 25
- ○ 26 - 35
- ○ 36 - 45
- ○ 46 - 55
- ○ 56 - 65
- ○ > 65

What's your gender? *

- ○ Male
- ○ Female

What is your occupation? *

- ○ Employed
- ○ Self-employed
- ○ Housewife/house husband
- ○ Student
- ○ Unemployed
- ○ Other: ______

What country are you living in? *

- Mexico
- United States
- Switzerland
- Denmark
- Netherlands
- India
- Other

Is there anything else you would like to share with us?