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Development of an in vehicle road user information interface

Master's Thesis in Interaction Design

MARIA KOUGIOUMOUTZI

Department of Applied Information Technology
CHALMERS UNIVERSITY OF TECHNOLOGY
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Abstract

In order to mitigate road accidents car manufacturers introduce in the market increasingly focused safety control systems, such as advanced driver assistance systems (ADAS). The current ADAS systems provide single stage warning features to alert the driver when the risk level rises over a certain amount. Theoretically if the drivers are mentally prepared, informed by advisory warnings prior to the collision warnings they are expected to respond better on a critical situation. Our aim is to enhance the driver's situational awareness by providing continuously real time information about the road users under normal driving conditions and not only when a warning has occurred. Based on this idea, three stages are introduced according to the threat level: informative, advisory and warning. The user interface we are introducing is designed to be perceived in an intuitive and natural way, not as a distraction but as an assistance in comprehending the outside environment.

Keywords: ADAS, Road Safety, User Interface, EID

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List of Abbreviations

ADAS	Advanced Driver Assistance Systems
UI	User Interface
EID	Ecological Interface Design
HMI	Human Computer Interaction
SA	Situational Awareness
TTC	Time To Collision

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Maria Kougioumoutzi

1. Introduction

Road safety is one of the most important and difficult challenges. Over 1.2 million people die each year on the world's roads, and between 20 and 50 million suffer non-fatal injuries [1].
Driving safe is a difficult task since the safety does not only depend on the driver's behaviour. There are many external factors, such as the road infrastructure or other road users that could lead to unexpected events. The driver has to consider all these factors and continuously adapt on the changing environment around the car.

In order to mitigate road accidents car manufacturers introduce in the market increasingly focused safety control systems, such as Advanced Driver Assistance Systems (ADAS). ADAS are part of the active vehicle related safety and they are systems developed to assist the driver in avoiding and mitigating accidents.
The term ADAS can cover a full range of systems varying from systems providing information, advice and warnings, through systems that assist and/or intervene in vehicle control and manoeuvring tasks, all the way to systems that support fully automatic driving [2]. Some examples of ADAS are Adaptive Cruise Control, Lane Departure Warning Systems, Intelligent Speed Adaptation and Collision Avoidance Systems.

The current ADAS systems provide information regarding the surrounding traffic environment through **single stage warning** features, alerting the driver when the risk level rises over a certain amount [3]. A single digital warning may cause confusion to the driver since there is very short time in order to interpret the warning and take the proper action. Moreover the information presentation from current ADAS is often binary on/off signal, only telling the driver whether there is hazard or not, but not what it is, or how dangerous it is. However, the binary warning signal is very hard for the driver to comprehend and react to when the stimuli activated. [4]

As a contrast to single stage warnings, a driver who is continuously informed by **graded warnings** regarding the traffic situation, will have more time to interpret the information and make a decision, avoiding reaching the critical warning level. In regards to this Lee, Hoffman and Hayes have conducted two experiments in which drivers interacted with an in-vehicle email system and a collision warning system signalling a braking lead vehicle. The first experiment showed that graded alerts led to a greater safety margin and a lower rate of inappropriate responses to nuisance warnings. The second experiment focused on attitudes toward the collision warning system and found that graded alerts were more trusted than single stage alerts [5].

Apart from considering having a single stage warning system or a graded warning system one has to consider the modality of the warning. There are three common modalities for presenting warnings: **visual, auditory and haptics**. Currently, there is not an official rule regarding the proper modality, but only suggestions. Scanning through the literature, some studies prove that since the visual field is already occupied, using a visual modality would increase the workload and thus auditory modality would be preferable. On the other hand, some other studies prove that using auditory modality could also increase the workload.

This study will elaborate on and design an **ADAS Graded Warning User Interface, using Visual Modality.** It will aim to assist the driver by providing **continuously** real-time **information** about the **road users**, under **normal driving conditions** and not only when a warning has occurred. The purpose is to enhance the driver's **situational awareness** and mentally **prepare** the driver sufficiently for good decision making in a critical situation.

The user interface of such a system, according to the HMI guidelines (section 3.6), has to be intuitive/self explanatory and the information provided can not be excessive. Since the focus of the study is the user interface of the ADAS system, the existing guidelines will be taken into consideration in order to make sure that the system does not compromise safety.

It is important to notice that the purpose of this system is not to replace but supplement the outer world. To enhance the driving experience by providing relevant traffic information, beyond the driver's sight, creating a wider awareness of the traffic situation which could pro actively shape the driver's behaviour towards safer interactions on the road.

To sum up**,** the **aim** of this study **is to design a user interface which provides continuously real-time, graded information about the road users.**

1.1 Research Question

This master thesis will try to answer the following research question:

"How should an ADAS graded warning user interface visualize real-time road user information?"

Finding the right information for this system is a part of the thesis research of Calin Giubega & Peter Chen, which will collect and specify the system requirements, together with my collaboration. How should the design fulfil these requirements will be the main focus of this study.

1.2 Limitations

This study is focusing only on the visual modality.

- Using a head up display was decided to be excluded, since it was not a part of the context of the study.
- The placement of the display is not part of the investigation, although it is preferable to be placed close the driver's eyesight.
- It is considering driving under normal driving conditions on daytime.

1.3 Technicalities / Backend

As mentioned above, the focus of this thesis is the interface design but it is important to understand how the backend of the system works. The system will be combining different adas features, using sensors and cameras located on the car in order to detect objects (road users) around the car. Several parameters both from the subject vehicle and the surrounded objects will be extracted in order to calculate the TTC (Time To Collision). The design will aim on visualizing TTC together with the road user type in a comprehensive way.

2. Background

This study is conducted in collaboration with Chalmers University of Technology and Safer Vehicle and Trafic Safety Center [6]. It is based on the masters thesis project of Bo Chang & David Marshall [7], developed as part of the Environmental Friendly Efficient Enjoyable and Safety Optimized Systems (EFESOS) [8].

2.1 Related Design

Since this is a novel project, there was a need of collecting ideas and inspiration regarding the interface design. In order to achieve that we investigated similar designs which are using visual modality.

- In the advanced intersection safety system implemented by the INTERSAFE project a similar approach has been taken. Before the driver enters the intersection he will have a direct visual link to the risk level computed by the system. With the proposed HMI, the driver can easily assess, if a situation is risky for his driving skills, or not [3].

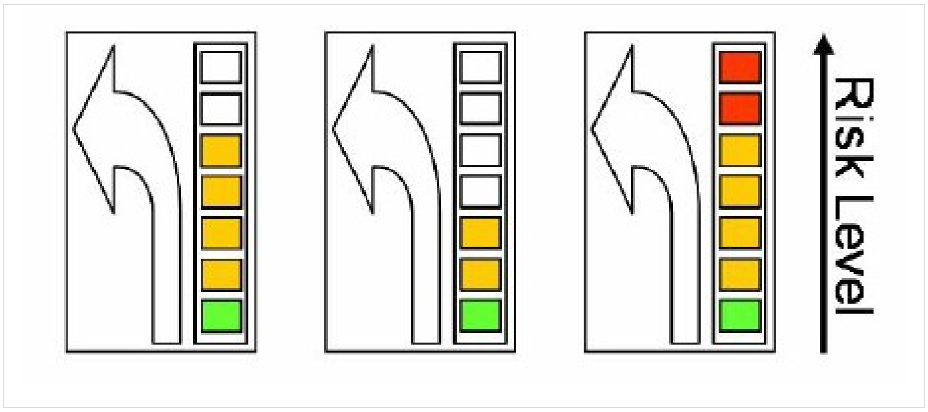


Illustration 1: The HMI design of the INTERSAFE Project for the visualization of the risk level.

This design was a great inspiration for our UI design since using gradient, colour information could help the driver perceive the level of threat.

- AUDI has introduced Audi Pre-sense [9], which is a four stage collision warning system for avoiding accidents and minimizing their consequences using among other features visual warnings. It categorises driving situations as critical or as an impending collision, with the aim of preparing the vehicle and its occupants as thoroughly as possible. The screen displays the cars which are about to collide in real time, with the use of color for the distance as well as warning text.

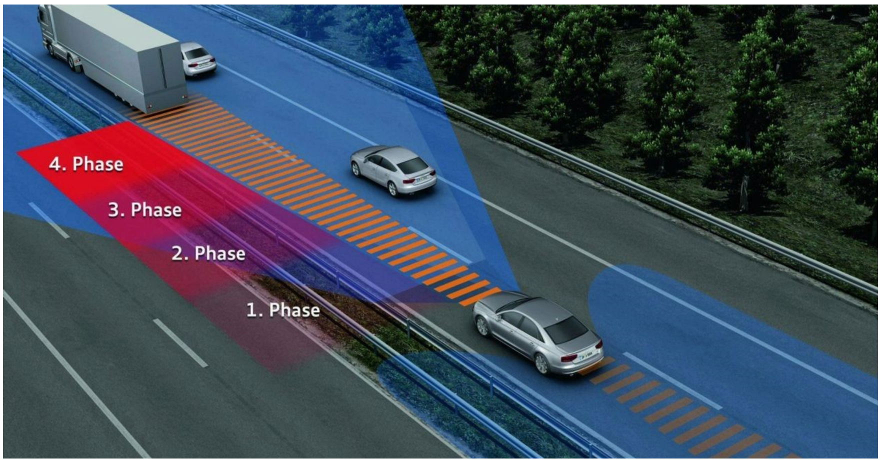


Illustration 2: AUDI A8 uses sensors in order to detect the vehicles within 70 meters and on the blind spots

Illustration 3: The visual warning of AUDI A8 safety system

The use of text in our UI design was avoided, as it may increase the driver's total glance time on the screen.

AUDI also uses computer vision for the night vision assistant with pedestrian detection. The system highlights the pedestrian using different colors depending on the risk level.

Illustration 4: The AUDI night vision assistant

- BMW park distance control visualizes the distance using sections with different colours [10].

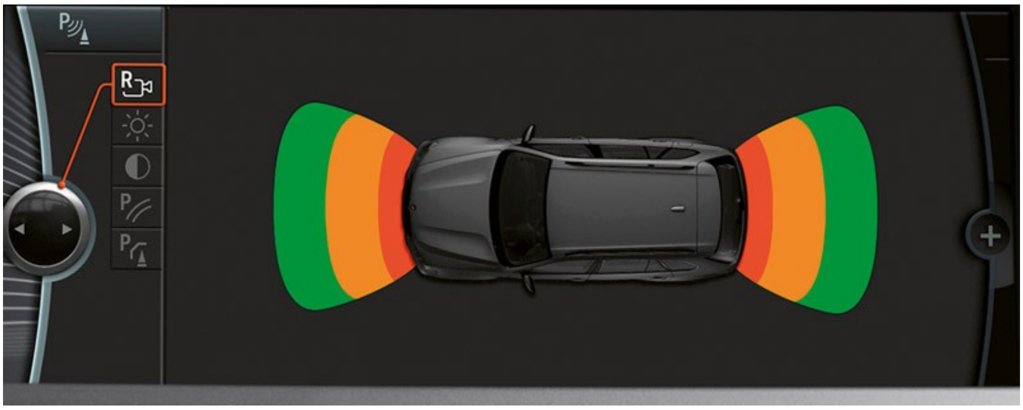


Illustration 5: The BMW park distance control

Green, amber and red are the most common colors used for these kind of systems since they are tightly connected to the driver's mental model regarding the traffic lights.

Green color was specifically avoided in our case, since it could provide a sense of safety which would not be preferable on our graded warning interface design.

Illustration 6: The BMW night vision assistant

BMW also uses a warning symbol for the feature “night Vision with person recognition” [11].

It is apparent that designing the icons or symbols for this system will be of great importance since the perception of the traffic situation depends on how well it is represented in the design.

From all the above designs, both negative and positive aspects were noted and some of them were applied on the design iterations, which will be provided in Chapter 5.

2.2 Previous Study

In the previous study, Marhall and Chang, implemented and evaluated two different designs in a driving simulator. Design 1 displayed only the direction information of road users around the driver while Design 2 presented direction as well as the type of road users. Naturalistic driving videos from Sweden and China were the basis for the driving scenarios. The driver's subjective feedback and collision rate data favoured Design 2 [7].

Illustration 7: Design 1 of the previous study

Illustration 8: Design 2 of the previous study

Illustration 9: The icons used in Design 2

While investigating Marhall and Chang's study, we found some drawbacks on the interface design, such as the use of too many icons. Since we had the chance to evaluate the design on a simulator, we noticed that the use of 5 different road user icons was resulting on cognitve overload, in addition with the the perception of the 3 levels of threat.

On our study we will take into consideration the elements used on the preferable design, such as regions, colors and icons but at the same time identify even deeper the system requirements for evolving the design.

3. Theory

In this section the literature findings are presented in relation to the problem and the aim of this study.

3.1 Situational Awareness

Three main stages of SA presented by Endsley (1995) [14] were constantly considered and referred to throughout the design process: Situational awareness is *the perception* of the elements in the environment within a volume of time and space, the *comprehension* of their meaning and the *projection* of their status in the near future [14]. Enhancing the situational awareness is the fundamental idea behind this system.

1. Perception of the elements in the environment

2. Comprehension of their meaning

3. Projection of the future status

An ADAS interface which enhances situational awareness over wider and larger areas than are normally scanned by driver’s view while driving could help drivers operate effectively more within their comfort zones and be more prepared in their encounters with potential hazards.

3.2 Advisory Warnings

As mentioned at the Introducion Chapter, one drawback of the warning design is time.
The timing of the alert is crucial for the driver's response on an event. An alert issued too early may be ignored by drivers if they are unable to perceive the cause of the warning. If an alert occurs too late, drivers may view it as ineffective, and it may even disrupt an ongoing braking process [12].
By providing advisory graded warnings prior to collision warnings, the drivers will have more time to process the information and take an appropriate action. Lee's experiment showed that early warnings helped distracted drivers react more quickly and thereby avoid more collisions than did late warnings or no warnings [12].

In previous work, Lindgren et al developed an ADAS interface design, using methods based on the Ecological Interface Design framework. These results also show that providing drivers with advisory information can have a positive effect on driver's behavior and make the driver more aware of the traffic situation. [13].

3.3 Mental Workload

Sudden increases in workload can occur during the interaction of the driver with the in-vehicle system, since the driver has to divide his/her attention between the outer world and the system inside the vehicle [15]. The way ADAS is implemented affects the driver's workload.
In contrary to phones and navigation systems, ADAS shouldn't be implemented as an additional system but rather as a background primary safety system. This prevents ADAS from taking up even more driver attention, as ADAS becomes part of the driving task [16]. The fundmental idea is to design the system, as an extension of the outer world, naturally integrated with the driving task.

3.4 Distraction

The term "driver distraction," is a specific type of inattention that occurs when drivers divert their attention away from the driving task to focus on another activity.
Secondary tasks, which are tasks not related to the primary driving task can cause visual, manual or cognitive distraction [17]. These types of distraction can affect decision making on critical situations.

Long (greater than 2.0 seconds) glances by the driver away from the forward road scene are correlated with increased crash/near-crash risk. When drivers glance away from the forward roadway for greater than 2.0 seconds out of a 6-second period, their risk of an unsafe event substantially increases relative to the baseline [17].

The interface design needs to be designed in a way that the total glances away from the road does not exceed the above limit. Theoretically, since the task is connected directly to the driving task, it should assist the driver instead of distract him/her. A further simulator study in combination with eye tracking should be able to measure the driver's distraction.

3.5 Perception

The way that a driver observes the area around the vehicle depends on how complex it is, and in complex environments, drivers can find it more difficult to identify the main hazards [18].

One explicit goal of visualization is to present data to human observers in a way that is informative and meaningful, on one hand, yet intuitive and effortless on the other [19].
Thus, our persistent purpose on the interface design will be to keep the elements, as simple, intuitive and consistent as possible.

Moreover, the preattentive properties of the objects such as form, color, motion, position, etc, will be carefully selected in order to assure that the driver will achieve an instantaneous identification of the situation. Preattentive processing occurs prior to conscious attention [19]. Typically, tasks that can be performed on large multielement displays in 200 milliseconds or less are considered preattentive [20].

3.6 Design Guidelines

There is a wide variety of design guidelines and standards in the literature regarding safety on in-vehicle information systems. Below are summarized the guidelines that are relevant to our system and assisted each stage of the design process.
The guidelines are divided into different categories and come from various sources.

3.6.1. Colours

1.1 The meaning of the colour coding should be clear and should conform to stereotypical norms, for example red for alarm and amber for warning. [21]

1.2 Red/green and blue/yellow combinations should be avoided since these colour combinations might be confusing for people who are colour blind [21].

1.3 The use of too many colours should also be avoided. A maximum of five different easy to distinguish colours is recommended (BS 5378 Part 1, 1980) [21].

1.4 Colours should be used consistently throughout the system [21].

1.5 It may be appropriate to have three levels of priority indicated by colour, eg 1) Red – Alarm, 2) Amber – Warning, 3) White – Information/Status [21].

3.6.2. Symbols and graphics

2.1 The graphics symbols or symbols should be consistent throughout the system and should not be too detailed or complex, as this can increase the time taken to identify appropriate information [21].

2.2 The comprehension of non-standard and unfamiliar symbols should be tested [21].

3.6.3. Image blinking

3.1 Blinking or flashing of any visual image should only be used to attract attention and inform about critical conditions [21].

3.2 Supplement color codes with other information to communicate the seriousness of a warning. Do not depend on colour coding to communicate the warning. Other coding schemes includes lashing and supplemental tones. [22].

3.6.4. General System

4.1 The design should be intuitive, self explanatory and non intrusive.

4.2 The quantity of information presented to the driver should not be excessive [21].

4.3 On first sight of a visual display areas of high contrast attract the attention [21].

4.4 The driver should be able to assimilate visual information with a few glances, which are brief enough not to adversely affect driving. A brief glance refers to glance duration of around 1 second representing the normal case and a maximum single glance of 1.5 seconds.
If the information cannot be acquired in a few brief glances driver workload and visual distraction may increase which increases also the risk of a crash [21].

4.5 The design should ensure that information presented to the driver should be correct, consistent and compatible with the traffic situation [21].

4.6 Keep backgrounds simple and muted [21].

4.7 The system should be designed in such a way that the allocation of driver attention to the system displays or controls remains compatible with the attention demands of the driving situation [22].

4.8 Minimize what the user has to remember [23].

4.9 Visual displays positioned closed to the driver's normal line of sight reduce the total eyes-off-the-road time relative to those that are positioned further away. Such positioning also maximizes the possibility for a driver to use peripheral vision to monitor the road scene for major developments while principally looking at the display [21].

Good interface design though is not merely a matter of complying with specific design requirements but must also include a process in which genuine attention is given to safety and usability. More than anything, this means following the Gould and Lewis (1985) design principles: (1) early focus on users and tasks, (2) iterative design, and (3) test, test, test [24].

4. Methodology

Illustration 10: Design Process InfoGraphic designed by Calin Giubega

4.1 UI Design Process

The process followed for the UI design was **iterative** and not linear.
The linear format of the design process, which was widely applied forty years ago, was criticised for suggesting that a problem could be solved in one go, so revised models that incorporate loops and iterative phases were developed [25]. For this project, design iterations were created and evaluated within the requirements elicitation process, as you can see on illustration 10 above. The input for each design method was the result of one or more requirements eliciation methods.

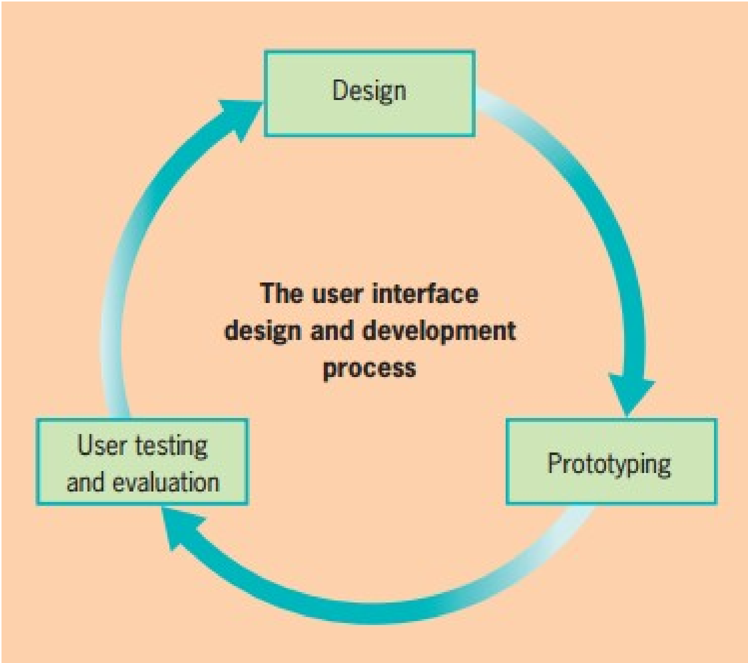


Illustration 11: The iterative user interface design and evaluation process [26]

UI Design Process Methods

The UI design methods which were selected to be the most relevant regarding the scope of this study are listed below. (Analysis of these methods is provided in the following sections).

- Brainstorming
- Sketching
- Expert Evaluation
- Prototyping (High fidelity and Video prototyping)
- Focus Group (Method also used for requirement elicitation)
- User Testing (Questionnaire)

Early user involvement & user testing

The Iterative design process included early focus on users. Since the user group was drivers with a valid driving license, it was easy to test each iteration.

The user testing was conducted in the forms of HMI expert evaluation, focus groups and pilot and final user testing which are all described below.

4.2 Requirements Elicitation

This part was implemented by Calin Giubega & Peter Chen together with my collaboration. In this chapter a short description of each method will be provided in order to comprehend the design process.

4.2.1 Ecological Interface Design

The methods applied on this interface design were based on the EID framework.
Ecological interface design (EID) is based on the concept that the constraints of the environment must be explicitly analysed to enable the direct perception of goal relevant properties of the environment. Thus it has particular promise in identifying ways to link the driver to the roadway environment [27]. Furthermore EID has theoretically the potential of improving Situational Awareness. First, we expect EID to support perception by making the constraints on effective action visible through graphical forms that are consistent with the perceptual capabilities and limitations of the viewer. Second, EID should support comprehension by communicating the purposeful structure of the system. Third, EID should support projection by supporting operator manipulations of the mental model that is externalized by the ecological interface [28].

4.2.2 Video Observations

In this study, traffic videos were used as mean of observing and analyzing constraints of the driving environment in the natural context of the activity.
An extensive video database was provided by SAFER [6], including around 100 traffic videos from both Sweden and China. The video extraction considered different aspects, such as the road types, the road users, the traffic density and finally the level of hazard situations. All videos were captured by a camera mounted on the dashboard of the car, which resulted in the fact that that the observer had a narrower field of view than the driver had in a real driving situation. This fact was taken into consideration during the whole observation process.
The traffic situations were observed from the perspective of reducing the number of critical situations while keeping the driver in the comfort zone. Therefore, both static and dynamic driving environment constraints were considered, identifying road user types and their state.

4.2.3 Video grouping

Categorizing the videos according to road types and road users was a relatively clear task, extracted naturally from the video the observations. The road types were divided into two main categories, low speed roads and high speed roads. Low speed roads included city and village roads, while high speed roads included freeway and national/district road. Inititally the road users were classified into 3 different types: pedestrians as vulnerable road users, vehicles and two wheel vehicles.

4.2.4 Video analysis using TTC factors

From the initial traffic video observation, an unclear part was the identification of the level of hazardous situations for each video. A measurement mean was required in order to classify the videos according to the criticallity of the traffic scenarios and the collision risk. At this point, Time To Collision (TTC) was introduced.
According to Horst, "Time-To-Collision (TTC) has proven to be an effective measure for rating the severity of traffic conflicts and for discriminating critical from normal behaviour. The results of several studies point to the direct use of TTC as a cue for decision-making in traffic" [4].
Marshal and Chang [7] used the following formula in order to calculate TTC in their correlated system.

$$TTC = \frac{\text{Distance between objects}}{\text{DriverSpeed - ObjectSpeed}}$$

The discussions following the video observations resulted to the fact that distance and speed could not be the only parameters affecting TTC.
An example which suppors that fact was a traffic scenario where the object (driver) is driving on a highway and on the opposite lane, cars are passing relatively close to the object. In this case the system would continuously show these cars as a critical warning, creating a false alarm. From our perspective, these cars should trigger the warning only if their trajectory or the trajectory of the object would change from parallel to non parallel. Thus trajectory and location was included in the TTC parameters.

From the driver's behaviour perspective some extra parameters were added; Speed, braking/accelerating and steering which will reveal the trajectory.

City / vehicles

#10

Pedestrian				Two Wheel Vehicles				Vehicles				Driver			
S	D	T	L	S	D	T	L	S	D	T	L	S	D	T	L
								constant	near	straight	front/ right	constant	near	straight	
								acceler- ating	near	crossing lane/left	back right	constant	near	straight	
A vehicle in the right is driving faster and towards the subject's car, crossing the lane. Here the driver should receive progressive information for speed, direction and danger level of the other vehicle															

Illustration 12: Table used for the TTC video analysis

In the above illustration the structure of the table used for this method is presented. For each video the TTC parameters were analyzed for both the road users and the driver (S represents speed, D - distance, T - trajectory, L - location) . The team discussed also how these parameters change according to passive or active behavior of the road users.

At this stage the first two analysis phases provided an initial level of road user information prioritization and a structure for providing relevant information for the driver, thus the gathered information was considered sufficient for conducting the first design iteration.

4.2.5 Brainstorming and prototyping

In order to initiate the idea generation the team conducted group brainstorming sessions. Brainstorming also called "green-lighting" is regarded as one of the most useful idea generators and one of the most successful discussion leading methods practised today [29].
The three of us produced quickly as many ideas as possible. The leader of the session encouraged the other members not to filter their ideas but instead to try to think out of the box. Some of the ideas were expressed as single words on a whiteboard and some others as paper sketches. Sketching is the simplest way for the designers to visualize their ideas. The drafts were not too detailed, but they could reveal easily our thoughts.

From paper sketches we created the first screen prototypes, where the best of the ideas were visualized. The design was developed iteratively throughout the whole process, as once the results of each method were analyzed and new requirements were added, the design was refined by adding, removing or changing basic elements. The most important iterations were also tested by HMI experts.

4.2.6 Video analysis using the driver's goal

An important observation finding was the need of prioritizing the events/road users in each traffic scenario.
Taking as an example the screen shot of a traffic video below, the system should consider how to handle the case where multiple road users are simultaneously present at the same area.

Illustration 13: Screenshot of a video where the need of road user prioritization is apparent

From the videos selected on the previous method, we analysed in depth some traffic scenarios that demanded prioritization between the road participants, according to the driver's goal.
In this method we analyzed in depth each traffic situation by writing a description, the driver´s goal, the information prioritization and finally possible design ideas.

This method could be also a base for creating the simulation scenarios which would come later, after the completion of the final design. One of the interesting results was that common patterns were revealed in many of the traffic situations. In very different occasions, the driver´s goal as well as the information prioritization was the same and in those cases the system would have the same visualization pattern. However there were some cases which were more challenging in the sense of prioritization and visualization.

4.7 Focus Groups

The methods described above for analysing the video observations, helped us to formulate the initial system requirements. Since there were ambiguous parts in the collected requirements a focus group session was planned and conducted with the goal of providing input about these requirements and also ideas about the design iterations.

Focus groups are a form of group interview that capitalises on communication between research participants in order to generate data. The advantage of focus groups in comparison to personal interviews is that the participants have the chance to interact with each other and further thoughts and discussions are created.
When group dynamics work well the participants work alongside the researcher, taking the research in new and often unexpected directions [30]. More than one focus group was decided to be conducted, one with HMI experts and one with interaction design students, since there was a need of expert evaluation as well as fresh ideas for our project.

The focus group was structured in three parts. In the first part there was a small introduction which included the aim of our study and purpose of the focus group. In the second part videos of different traffic scenarios were displayed, followed by a relevant question and a discussion. The purpose was to present different scenarios and discuss about which is the useful information for the driver in these specific cases. For most of the videos the design iteration was also provided, either as a picture or as a small animation in order to give them an idea of how we perceive visually the system.
The third part included the discussion around the main structural requirements, such as the grouping of road users, the TTC parameters and the grouping of road types.

The first focus group was conducted with 5 participants from the HMI area. One of the three team members was selected as moderator. The task of the moderator was to present the information and lead the discussion making sure that all the particants take part equally. It was important for us that the participants comprehended the main aim of our study so that they could discuss further within the right context. After introducing the aims of our study and while having started with the questions, we realised than not all of the participants were on the right track. Thus some extra time was added on discussing the project including more detailed information. After resolving this issue, we had some more effective discussions. Participants had contradicting opinions which led to interesting interactions between them. One of the findings of the first focus group was that some of the HMI experts were quite biased from specializing on a specific domain and that effect influenced the discussions.

The second focus group was conducted with five students from interaction design, all of them in their second and final year of studies. The structure was the same, but this time we made sure everybody comprehended our aims before continuing with the discussions. In terms of feedback and input this focus group was more successful and we discussed some parts that were not brought up in the first focus group.

In order to analyse the results the recordings of the discussions and the notes were documented. We went through each one of the comments and we removed the redundant, organizing them in categories, according to the type of the comment (design suggestions, general requirements, etc). The next design iterations as well as the requirement formulation were influenced from the results of the focus groups. In conclusion the focus group allowed us to confirm that the requirements already collected were on the right track and that a further discussion and research for solving certain issues had to be done, focused on the results of the focus groups.

5. Execution / Design Iterations

The design iterations were implemented, according to HMI design guidelines, literature findings and the results of the applied methodology. In this part the design iterations are described in detail providing the motivation behind each design decision. The software used for the design iterations was Adobe Photoshop.

5.1 Design Iterations

5.1.1 Iteration #1

The first iteration was developed as soon as we had collected part of the initial requirements which had resulted from the video observations (Section 4.2).
A main input for this iteration was also the findings of the video analysis method using TTC (Section 4.4). TTC, was used as a way of distinguishing the level of threat for road users in traffic situations. Through this method the three different levels of threat were formulated (informative, advisory, warning) and in the illustration below you can see the first attempt of visualizing them.
This approach was also recommended from the guideline x.x: It may be appropriate to have three levels of priority indicated by colour, eg 1) Red – Alarm, 2) Amber – Warning, 3) White – Information/Status (Guideline 1.5).
All the colours were tested for being compatible with colour blind people, according the to the Guideline 1.2.

Illustration 14: Screenshot of the first iteration

Shape

Influenced from the design of the previous project [7] we initially sketched a round shape. This shape could complement the positioning of the display, as shown in illustration 14. Radars was also an inspiration for designing a round shape.

Regions

The area around the car was initially divided into six sections. Front, front right, front left, back, back right, back left. In these sections the blind spots were not included as the initial requirements did not consider blind spot information.

Icons

The icons of the first iteration were created according to the initial grouping of the road participants (Section 4.3). The icons consisted of the main road users, surrounded by a triangular shape, influenced by the warning traffic sign. The color of the icons was chosen to be white in order to create contrast with the black background (Guideline 4.3).

Since this was a draft iteration the detail of the icon was not of great importance. We picked the classic road user icons, surrounded by a triangular shape.

Informative level

In this first iteration the informative level was represented by the appearance of the road user's icon in the section where the object was detected. This resulted from the initial general requirement “The system should provide continuously information about the road users. In particular, their location and the level of threat.” Since this level is informing the driver about the appearance of a road user near the driver's vehicle but not as an immediate threat, the icon of the road user was enough to represent the situation.

Advisory level

The advisory level, in contrast to the informative level which should be subtle, should attract driver's attention, however in a non intrusive way. The driver should be visually guided to pay attention to the information provided on this level and consider taking an appropriate action in order to minimize the threat. When designing the different levels, we tried to keep in mind that the elements used should be easily detected by the driver's peripheral view. This was achieved by keeping the road user icon and filling the whole section where the object was detected with yellow color. When considering warning colours, Lerner et al. (1996), Stevens et al. (2002), and Campbell et al. (2007) recommend using yellow/amber as the colour for the cautionary warning level.
This specific approach, of filling the whole section with colour, was adopted from the very first iteration and was preserved until the final one with various refinements.

Warning level

The difference between the advisory and warning level for this iteration was the use of colour. Yellow was replaced with red, since it is the most appropriate color for indicating alarming situations (Guideline 1.1).

5.1.2 Iteration #2

Illustration 15: Screenshot of the second iteration

The second iteration was created right after the brainstorming session (Section 4.5). As mentioned before, the first iteration was a draft visualization of our ideas. The second iteration was focusing more on details of the design and in illustration 15 you can see the result. The modifications on the design are analyzed below.

Icons

The triangular shape around the icon was removed as the testers noticed that in the informative level, the connection to a warning sign could make it perceived as a higher threat than it is. In order to keep the consistency, it was removed from the other two levels. The size of the icons was also reduced.

Informative level

In the first iteration, the informative level was represented by only the road user icon. The team decided to experiment with the addition of another element on this level. This element had to remain subtle, since the objective is to simply inform the driver about the presence of an object.
Thus, a thin white line was added, covering the peripheral of the section where the object is detected. Using this line away from the center of the design, it could create a noticeable difference than placing it close to the center.
The line aimed on indicating that a road user, which is represented by the icon, is approaching in the specific section. The line was kept for the other two levels where more information about the level of threat was added, using the appropriate colour. (see illustration 15)

Gradient Information

By formulating three different levels of threat, the driver is assisted to comprehend the criticality of a traffic situation. The addition on this iteration was the idea of having gradient presentation of the threat even within these levels in order to enhance even more the perception and awareness of a situation.
In order to achieve that we took advantage of the color's saturation property. The saturation of the color depends on the TTC value, thus the advisory information will start with low color saturation, progressing towards full color saturation as the TTC value decreases which means that the risk level increases. The progressive saturation of the advisory level will not only represent an increasing level of threat but it will also help the driver in decision making by differentiating between two or more advisory regions (illustration 15). This gradience was applied both on the advisory and the warning level.

Advisory level

The colour of the advisory level was a big part of our discussion.
One idea was to use the colour gradience from yellow to amber and the second one was to use the gradience within yellow or amber color.
It was finally decided to use only one color since theoretically it would be easier to connect it with the advisory level. This was based on the fact that adding one more color could possibly add on the driver's workload (Guideline 1.3). In addition different cultures perceive colors with different meanings. Testing the use of colours (yellow or amber) would help us comclude to a final decision.

Depth option

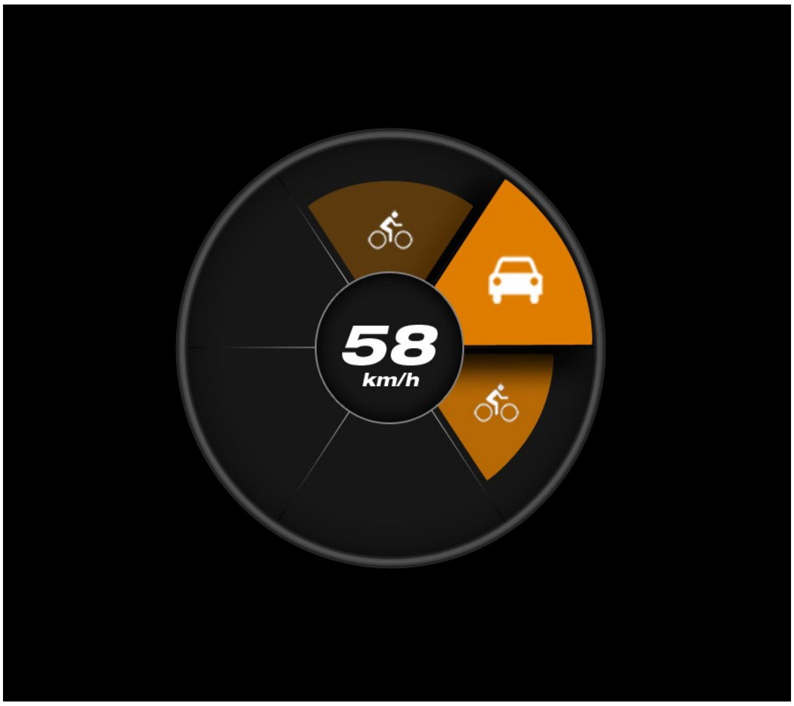


Illustration 16: The depth option of the second iteration

One of the requirements which resulted from the analysis method using TTC was the need of prioritization of the traffic participants (Section 4.4).
During the design of the second iteration, the prioritization was considered as differentiating visually the road users by applying a depth effect, as shown on illustration 16.
This effect was planned to be tested, since there was a possibility that it could demand higher cognitive effort, when combined with the color gradient and the interpretation of the road user icons.

5.1.3 Iteration #3

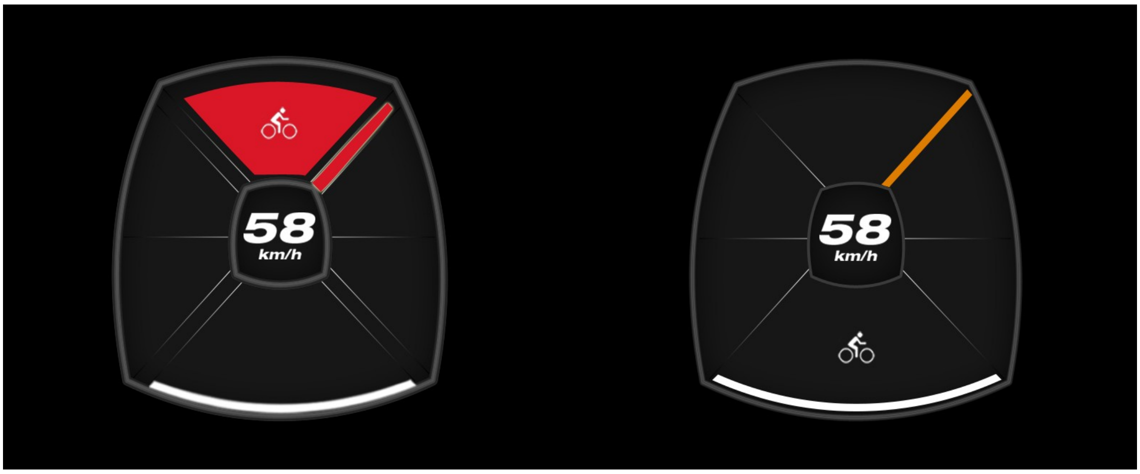


Illustration 17: Two different versions of the third iteration

For the previous iteration (#2), a small animation was created using the Adobe Photoshop animation feature. The purpose of this animation was to test how do the three levels of threat perform in a traffic scenario. This iteration resulted from the feedback of a short user testing with two HMI experts.

Shape

During the HMI testing of the second iteration, we received some negative feedback regardind the shape of the design #2. By observing carefully the animation, the experts noticed that the round shape was not the optimal solution. When a car was presented in the screen as informative, moving for instance from the left front to the left back area, it could be easily misinterpreted as moving towards the back area of the car, even if that did not occur.
There was the need of designing another shape which would not confuse the user in relation to the positioning of the obstacles and would not create the impression of false direction. Dozens of different shapes were sketched in order to conclude in the shape which is shown in illustration 17. Another testing session should be planned in order to evaluate its effectiveness.

Blind spots

From the video analysis using the driver's goal (Section 4.6), the need of blind spot information was revealed. Showing what is happening in the areas around the car where the driver has difficulty in being aware physically, such as the

blind spots, is a main advantage of such a system and the design should provide clearly this indication.
As shown in the illustration 17, the blind spots were designed as thin lines, with the colour indicating the level of threat. For this iteration, the information about the type of road user on the blind spots was not presented, in order to keep the design simple and less crowded, but the importance of the road users for the blind spots would be tested further.

Warning level

Another input from the HMI experts regarded the representation of the warning level. The only differentiation between the advisory and the warning level was the colour and the question was if the colour was enough for indicating the critical situations.
According to ISO/DIS 15008 image blinking (or flashing) should be used only to attract attention and inform about critical conditions requiring immediate attention. Thus for the warning level, the red colour was supplemented with flashing in order to communicate the seriousness of the warning [Guideline 3.1/3.2].

Furthermore the white line used in the informative level was removed from the advisory and warning level as it was only adding visual load without having a specific purpose.

5.1.4 Iteration #4

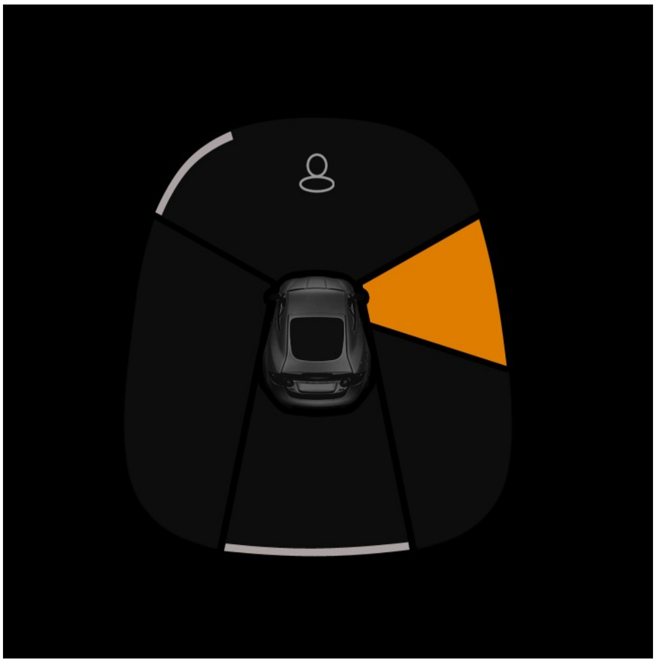


Illustration 18: Screenshot of the fourth iteration

The focus groups, described in the section 4.7, proved as an effective method of receiving feedback and input regarding the requirements and the design of the system.

Road users

The most basic change which resulted from the focus groups was the grouping of the road users and the representation on the design.
According to many participants, the design was using too many icons and since the driver had to look on the screen in order to distinguish between the road users (level of detail), this would result on a negative effect on the driver's behavior. According to guideline 4.4, the driver should be able to assimilate visual information with a few glances, which are brief enough not to adversely affect driving. If the information cannot be acquired in a few brief glances driver workload and visual distraction may increase which increases also the risk of a crash.
In the iteration presented on the focus groups, four icons were used according to the road user type: vehicles, two wheel vehicles, cyclists and pedestrians.
In the discussions, the importance of presenting all the road users was questioned. The use of an icon for the pedestrian was mandatory according to the participants while all the other road users could form a separate group since they have a route/plan. Everybody agreed that the pedestrians are completely unpredictable.

The final decision on presenting road users included also the bicyclists, since traffic accidents involving bicyclists and pedestrians result in a higher rate of fatal accidents [31]. Thus a single icon was designed in order to represent the vulnerable road users which are the pedestrians and the bicyclists (illustration 18).

Icon design

In the current literature, there is no official icon for the vulnerable road users. Since only one icon was decided to be used, it would be easier for the driver to identify that the presence of the icon means that a vulnerable road user is on the road. If one of the levels was triggered without the icon it would mean that either a vehicle or a two wheel vehicle is on the road. Even though the driver would be instructed for the meaning of the icon, it should be intuitive.
One idea regarding the icon was to include both the pedestrian and the bicycle on the design, similar to a traffic sign (illustration 19).

Illustration 19: A pedestrian/bicycle road sign

According to the guideline 3.1 on section 3.6 "The graphic symbols should be consistent throughout the system and should not be too detailed or complex, as this can increase the time taken to identify appropriate information".

Such an icon, designed with higher level of detail, would demand higher cognitive effort (Guideline 2.1) and it could also lead to confusions, such as that the driver could assume that both a pedestrian and a cyclist is on the road, even if that did not occur. For general or abstract concepts, less detailed symbols such as caricatures or silhouettes are most appropriate [32].

This icon is representing two different types of road users, thus a more general, abstract icon was designed.

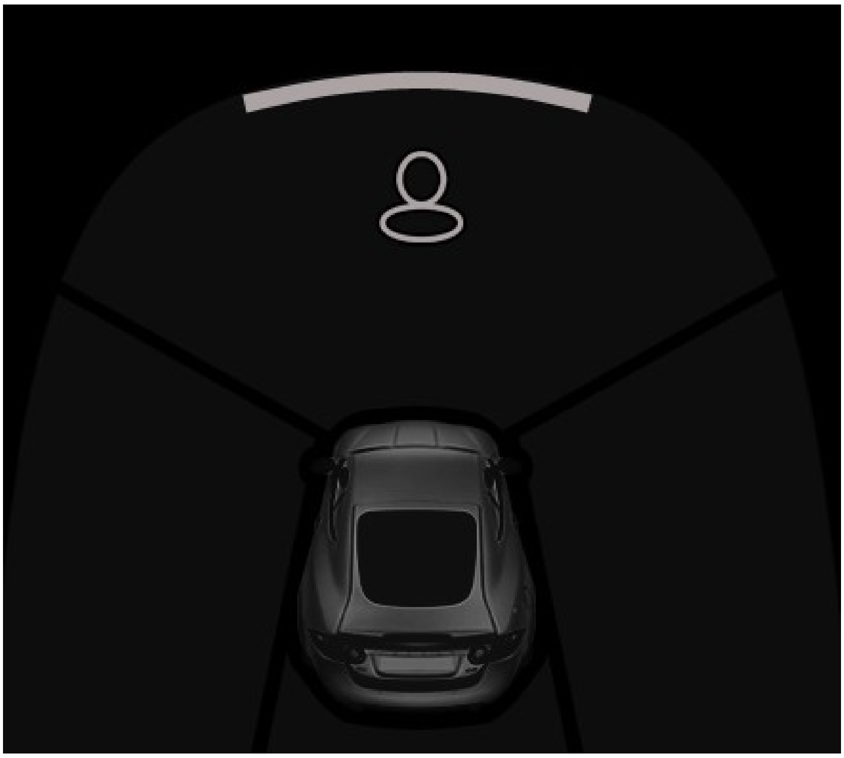


Illustration 20: The vulnerable road user icon on the informative level

The driver acceptance of general or specific icons is an important aspect in order to minimize driver memory requirements and system complexity. Well-designed general icons will be acceptable to most drivers under most driving circumstances [32].

Recognition of an icon, reflects the relationship between the driver, the icon, and other icons or visual display elements. It includes issues such as whether the driver can identify the icon, especially in the context of other symbols and icons [33]. In our interface this would be the only icon, thus the driver should recognize it easier.

The colour of the icon, as well as the colour of the informative line changed from white to grey, in order to make it more subtle, since it was noticed on the focus group that the big contrast between black and white could attract too much attention.
Once the informative or the warning level is activated the colour of the icon is changing to black in order to create a good contrast with the amber or red colour.

Regions and Blind spots

Regarding the blind spot information, it was noted on the discussions, that there was a big difference in size, compared to the other regions (the blind spot regions were smaller) and there was no information about the type of road user located on the blind spot. Everybody agreed that the blind spots should have high priority on the design as a big advantage of this system is that is is possible to provide information about what the driver can not view physically.

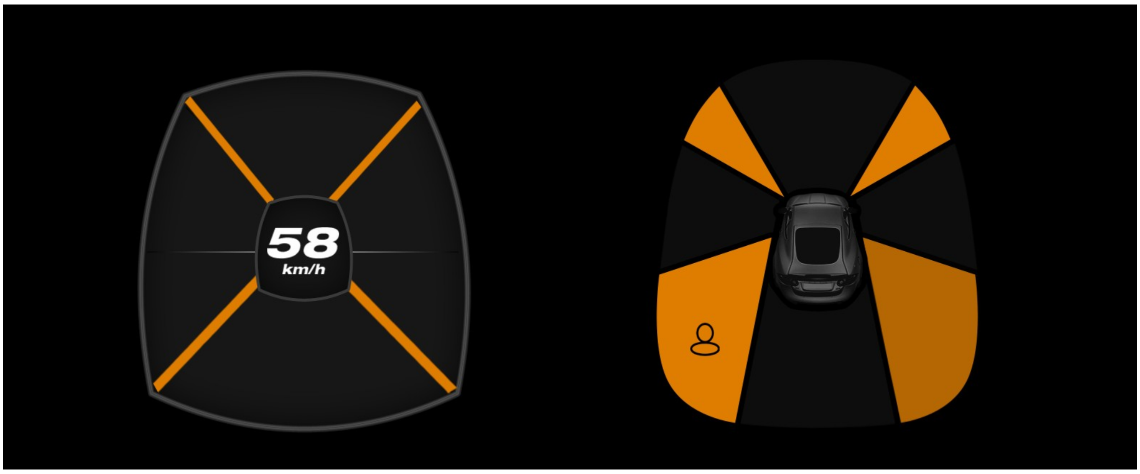


Illustration 21: On the left is the blind spot region from the previous iteration and on the right the new regions.

In illustration 21 you can see how the blind spot areas were presented on the new design. The blind spot areas were designed as close to the reality in order to naturally map the area around the car. The display of the icons were handled the same way with the other regions, keeping the consistency of the system. On one hand the regions were increased, and more elements were added on the design, but on the other hand this information would be critical for increasing situational awareness and avoiding accidents which commonly occur because of the car's blind spots.

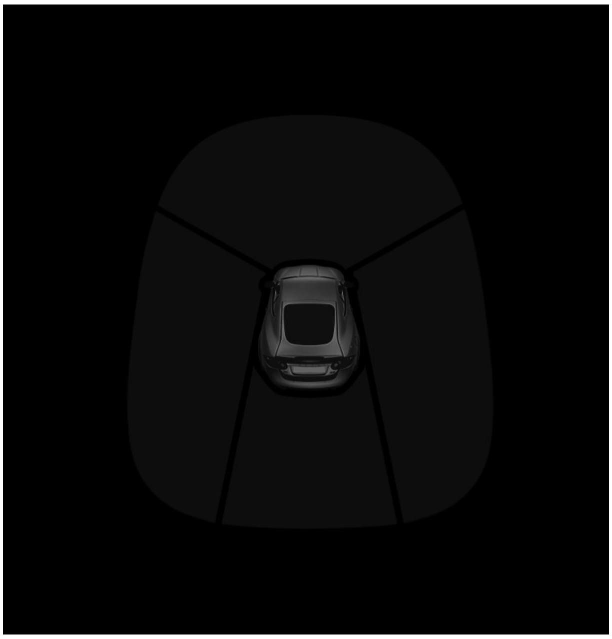


Illustration 22: The regions when the system is idle.

The regions are divided into four basic areas when the system is idle; front, back, right, left (illustration 22). According to guideline 4.6 the background should be simple and muted. As soon as a road user is detected, the triggered region becomes active, providing relevant information.
In the front section of the design the area is divided into front, front right, front left. The back area is divided into back, back right and back left (illustration 23).

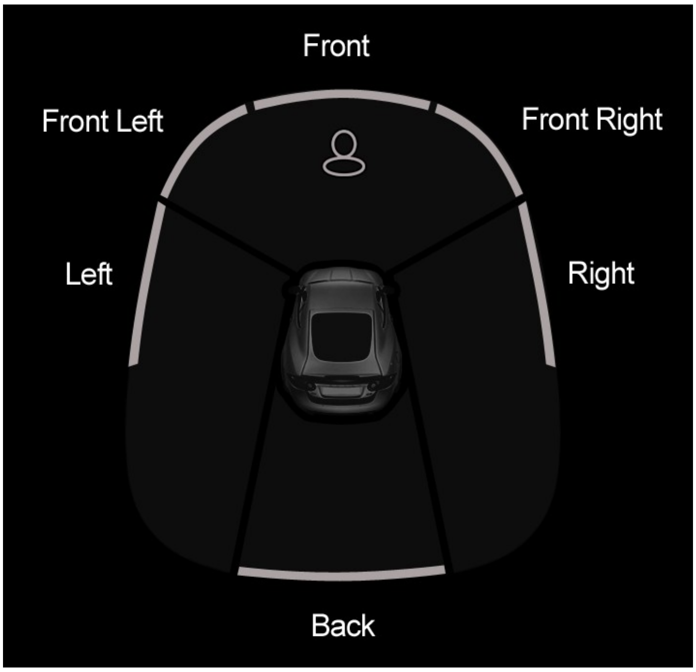


Illustration 23: The regions when the informative level is activated (without the blind spots).

As soon as a pedestrian is detected on one of the blind spots, the front right or left blind spot is activated providing a more precise information by displaying a more accurate angle. The displayed angle for the blind spots represents the area covered by the A-post (wind shield frame), of the car. The side areas are also divided in two parts, the front side and the blind spot.

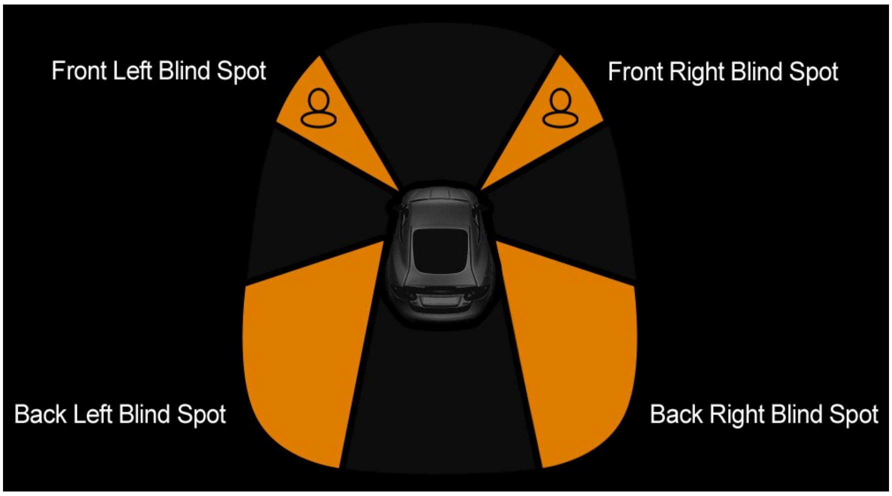


Illustration 24: The blind spot regions when the advisory level is activated.

Illustration 25: Simulation of the forward looking blind spot (FLB) [34]

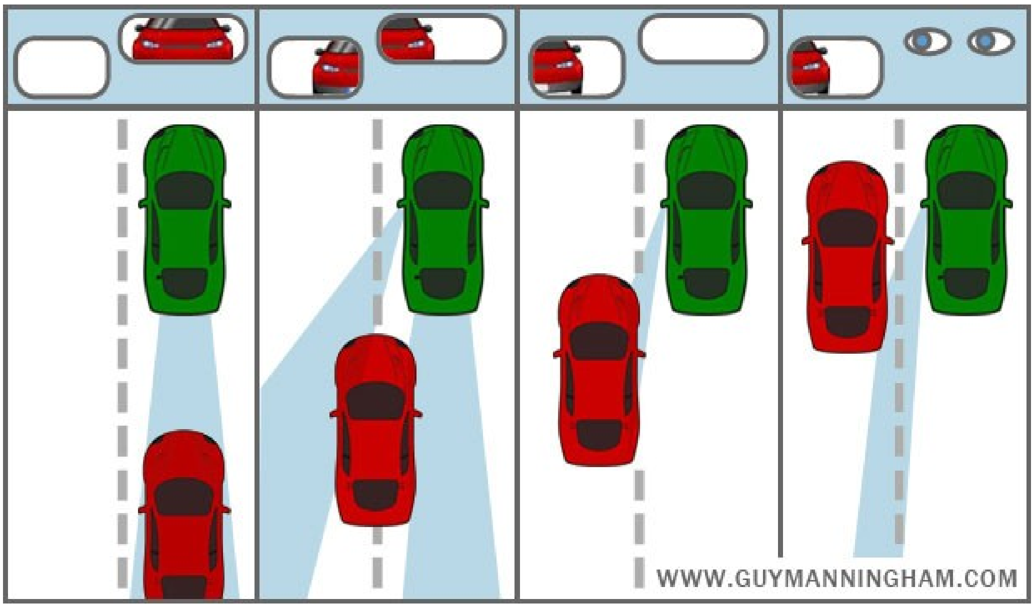


Illustration 26: The rear side blind spots [35]

Shape

Since there was still an ambiguity regarding the perception of the shape, the speed indication in the centre was replaced by a vehicle image, in order to enhance perceiving the areas around the car. The edges of the shape were rounded in order to imitate the car's perspective.

Depth option

The depth option (illustration 16) was presented on the focus group, as a mean of visualizing the prioritization between the road users. The discussions followed resulted on removing this feature since it was adding visual demand. Instead of presenting visually the prioritization of the road participants the system would handle the vulnerable road users in a different way, since they are more unpredictable. That means having less threshold for the calculation of the TTC.

5.2 User Testing

5.2.1 Prototype Implementation

The next step after finalizing the design was to create a high fidelity video prototype which would be a part of the user testing method.
The core idea for the video prototype was to create a video which would consist in a real traffic scenario merged with an animation of the user interface operating in real time (illustration 27). The users would be able to see the events happening on the road and at the same time how the system responds visually. The videos were recorded from the driver's perspective, by a camera attached on the dashboard. In that case the design could be placed in the lower part of the video, as in the reality it would be placed near the driver's sight. The events of the system were synchronized as close as possible with the traffic scenario.

Illustration 27: Screenshot of the video prototype

After watching the traffic videos which were collected on the video observation phase, three of them were extracted, with high importance regarding the traffic scenarios. Two of them included vulnerable road users and all of them included situations which would trigger all the possible levels (informative, advisory, warning).
The animation of the design was designed in Adobe Photoshop and the merging of the two videos was implemented in Adobe Premiere.

5.2.2 Pilot user testing

A pilot user testing of 5 questions and 5 participants was conducted. The goal was to check if the users perceive and comprehend the design at a first level and to test the use of the video prototype. The results were satisfying, thus the final user testing was implemented as planned (See appendix A).

5.2.3 Questionnaire design

No matter how much analysis has been done in designing an interface, experience has shown that there will be problems that only appear when the design is tested with users (Lewis and Rieman, 1994). When deciding on the evaluation method to be applied for this project, the purpose of the method was taken into consideration. The main aim of the user testing would be first, concluding on certain design elements, such as the icon or the colors and second the perception of different levels and the general acceptance of the system. In other words the purpose of the testing would be to gather data which would provide the input for refining the design and creating the final design iteration for the simulation testing. Since the users would have a passive task, watching the system operating, many of the usability methods which require the user to carry out tasks (using the system) were excluded.
One of the methods that fit well with the purpose of the testing was the questionnaires. Questionnaires are considered an easy and inexpensive method for obtaining and analyzing data. The main disadvantage of the questionnaires though is that the scaled questions, even if they are easier to quantify, limit information that may be obtained through open ended questions [36].
Thus, a questionnaire which merged closed and open-ended questions was designed.
For the rating, a Likert type scale from 1 to 5 was used, where 1 represented “slightly” and 5 “strongly”.

12 users in total, 6 men and 6 women, from 24 to 48 years old participated in the testing. The optimal setting for this kind of user testing would be to display the traffic video separately, through a projector on the wall and the simulation video of the interface on the same 7 inches screen which would be used on the simulation testing. The driver's placement on the driving seat would create a more realistic setting. However this kind of testing was not available at the time that the user testing was performed, so the users were sitting in a desk, watching the video on a 21 inches lcd screen.
Before the user testing, no description or specification of the system was provided in order to test how the users perceived the elements of the design.

The questions

The questionnaire (see appendix B) consisted of two parts and sixteen questions in total. The first part included general demographic data (gender, age) and personal information regarding driving. The only prerequisite of the user testing was that the participants should have a driving license and the years of driving was part of the information gathered for further analysis. Since the years of driving is not the only parameter determining the users driving experience, the frequency of driving was also questioned in the first part.
The second part consisted of questions testing different elements of the design.

The levels of threat

In detail, the first three questions were about the three different levels of threat. An example question, regarding the informative level is presented below:

"While you were watching the video, in what level did the gray lines manage to capture your attention, shown on the screen shot below. "

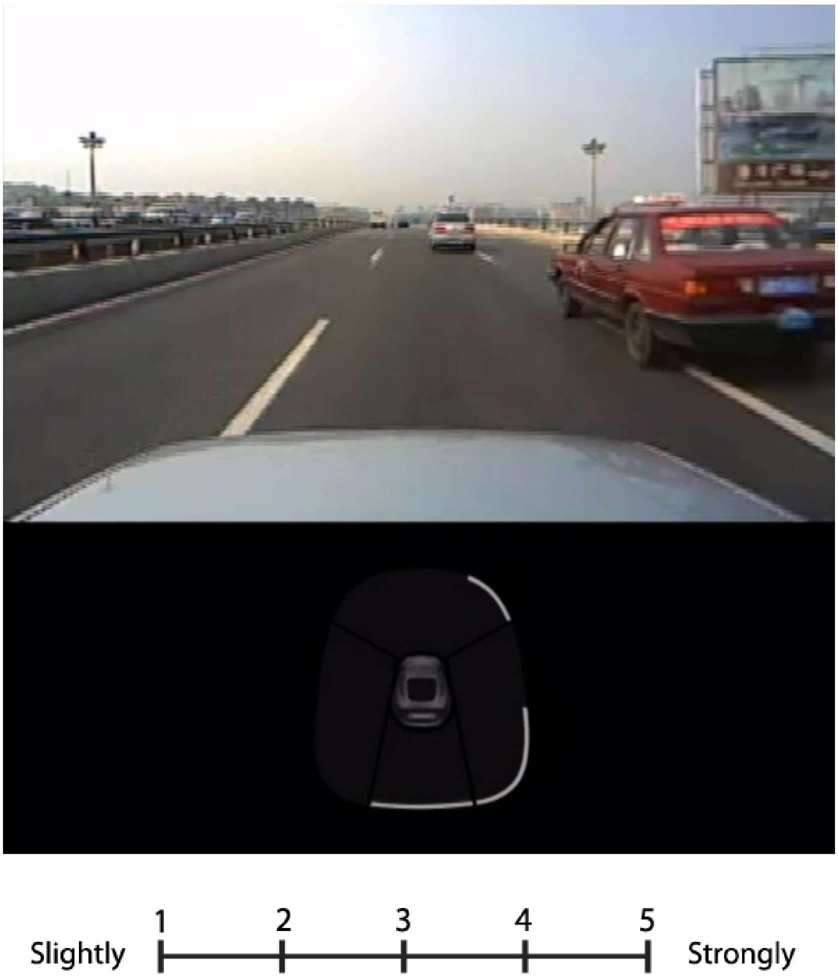


Illustration 28: The screenshot and the scale provided on the first question of the questionnaire

This question was aiming on testing the visibility of the gray lines, used on the informative level for visualizing the presence of a car. The informative level is aiming on presenting the information in a subtle way, since it will be often activated, even in a normal traffic situation. Thus if we received from the results an average of three for this question, it would be accepted as a good result, and no changes would have to be made. If the result would be 5 or 4, then the design would have to be reconsidered since it would attract more attention than intended. The same applied to a possible 1 or 2.

The second part of the question, was an open-ended question considering the perception of the informative level:
"For the same screen shot, how did you perceive the gray lines? What do you believe they represent?"

This question was aiming on testing how intuitive was the design for the users. Since the participants did not get instructed about the system's goals and functionality, asking about the perception of the elements representation on the informative level would possibly reveal the intuitiveness of the design.

The same questions were applied for the advisory and the warning level, providing relevant screen shots of the videos.

The icon

The next questions regarded the effectiveness of the icon in representing pedestrians and bicycles (vulnerable road users). As mentioned in the section 6.1.4, since there was no official icon or this group of road users, the icon should be tested.

The first question was formulated as follows:

"How effective was the icon in representing the vulnerable road users (pedestrians, cyclists)?"

Illustration 29: The screenshot provided on the question #10 of the questionnaire

Illustration 30: The screenshot and the scale provided on the question #10 of the questionnaire

The graded scale was followed by a comment section where the participants could express their opinions besides rating the icon. The quantitative data from this question could help as an input in redesigning the icon if the results were not good.

The second question regarding the icon, was formulated as follows:

"How effective was the icon for distinguishing the vulnerable road users on the street?"

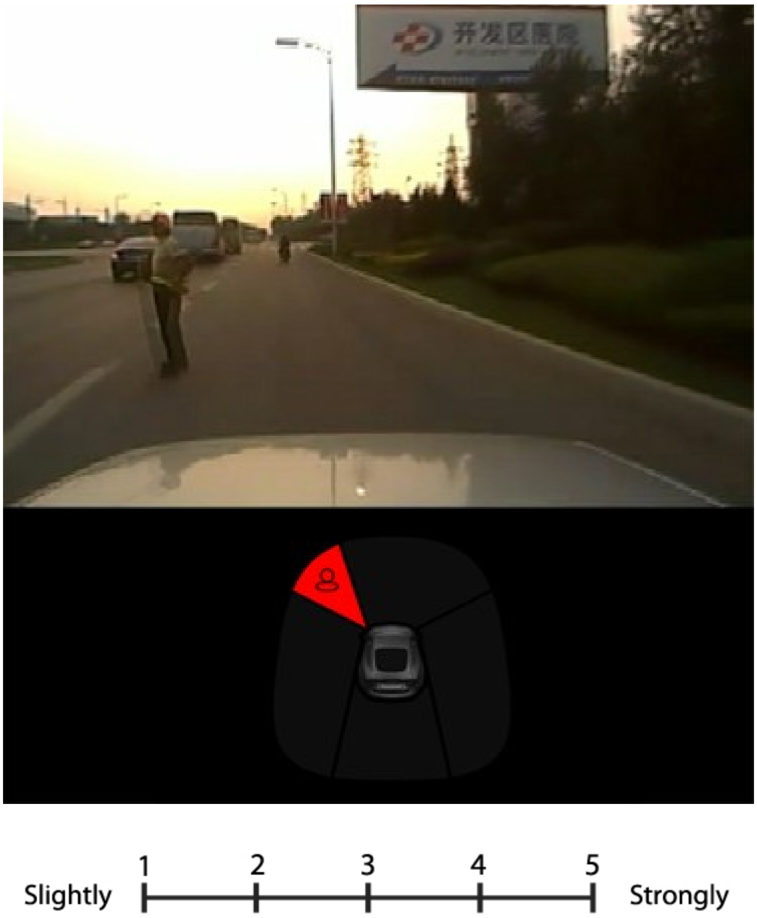
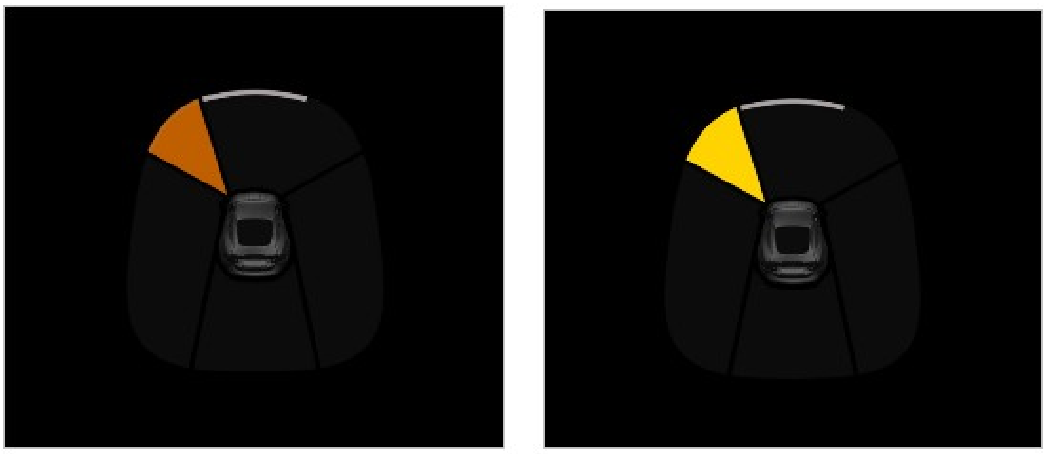


Illustration 31: The screenshot and the scale provided on the question #9 of the questionnaire

There were a lot of discussions in the design phase about assigning visual priority to the vulnerable road users and this question was focusing on revealing how much the icon was helping in distinguishing these type of users on the street. As in the previous question, comments were welcome in order to let the users reflect on their decision.

Testing design elements

For the next five set of questions the participants were asked to choose one out of two screen shots which was presenting the higher level of threat in the front left section.



☐ a. ☐ b.

Illustration 32: The screenshot provided on the question #12 of the questionnaire

☐ a. ☐ b.

Illustration 33: The screenshot provided on the question #15 of the questionnaire

The testing included also the choice of colors for the different levels. In section x.x, the choice of colors was questioned, whether to use a gradient between yellow and red or strictly the amber and red color. In this section, the participants were asked to choose which color represents the higher level of threat. In case that the results were not correct, yellow was decided to be excluded since it was contradicting with the goal of the design to be perceived intuitively.

Illustration 34: The screenshot provided on the question #14 of the questionnaire

Amber and red, the colors of advisory and warning level were also tested, in order to prove if the choice of the recommended colors were correct.

Finally the participants were asked to rate the usefulness of the system.

6. Results & Analysis

In this part the results of the user testing are provided together with the final iteration. The different design iterations can be considered as part of the results but they are provided in the previous chapter instead as the execution part, showing how the final iteration was evolved.

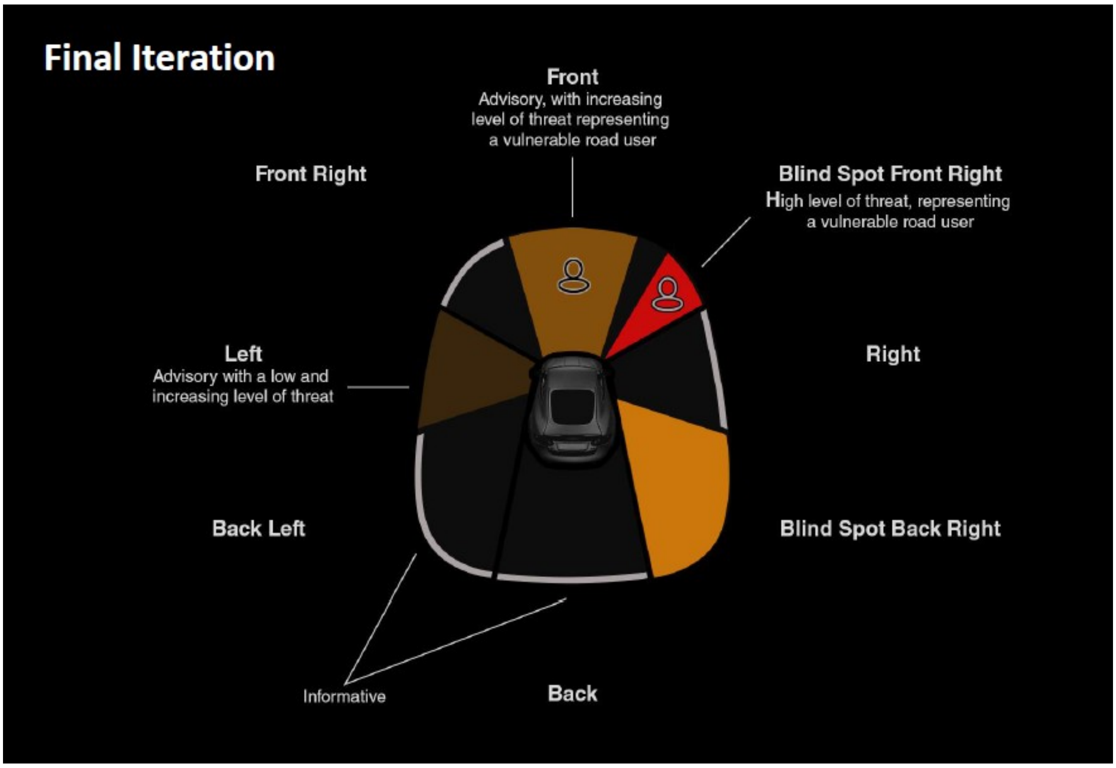


Illustration 35: The final design iteration

As mentioned above, the first part of the questionnaire included general demographic data (gender, age) and personal information regarding driving. In the second part of the questionnaire, the first question regarded the ability of the three levels to attract the user's attention. The informative level received an average value of 3, the advisory an average of 4 and the warning 5. (1 equals “slightly” and 5 equals “strongly”.)
No changes were decided to be applied on the design since this result agrees with the expected results from the requirements gathered; the informative level should be subtle, the advisory level distinguishable and the warning level should not be ignored.

If the warning level for instance was hardly noticed, the design of that level would have to be modified in order to increase its visibility.

The second part of the question regarded the perception of the three levels of threat was tested and from the qualitative data collected, it is concluded that the users were able to perceive in a high degree the purpose of the design, without getting instructed.
For instance, regarding the perception of the **informative level** one of the participants answered: *"I think it tells the driver that there are objects close to the car but in a distance that is not yet alarming. They were very subtle at first but after getting used to them they provided good indication about what is happening outside of the view."*

Regarding the perception of the **advisory leve**l, another participant answered: *"At first they caught my full attention and made it hard to concentrate on the street but after getting used to it I could notice it without turning my view away from the street. I think they represent objects that would cause a collision when keeping the direction but it should not be a problem to avoid them when action is taken immediately."*

Finally regarding the perception of the **warning level**: "Like the previous, but in this case the vehicle is even closer and you should do something about it."

Since all of the participants answered correctly the perception questions, it proves that the design is quite intuitive and that the elements chosen are effective on visualizing the levels of threat to the user.

Icon

The first part of the icon question regarded the effectiveness of the icon in representing pedestrians and bicycles (illustration 29 & illustration 30).
It received an average value of 4, which can be interpreted as a good result.
Below are some of the participant comments:

"I think the icon was good in the sense that in some cases I did not see the pedestrian until I saw the icon and I realized he should be there somewhere."

"I think it is quite good because it is simple and understandable."

"I think it is a clear symbol and I understand it and I think it works to have the same for pedestrians and cyclists. It could be confusing with more."

The second part of the question provided a screenshot of the system where the icon was used in the advisory and the warning level and the participants were asked to answer how effective was the design in these cases for distinguishing the VRU (illustration 31). The result was an average of 3 and from the open question followed the participants commented that they had difficulty noticing the icon.
Particularly one of the participants commented:

“I think the icon was quite effective because of the color too. The color grabbed my attention and I also saw the icon. It helped to notice people if I hadn't noticed them before”.

Thus, in the final iteration it was decided to add an element in the icon which would make it more distinguishable on the advisory and warning levels.
That element is a grey outline which is shown in illustration 36.

Colors

Five of the questions aimed on concluding to which colors should be used on the final design. It was resulted that red was perceived as higher level of threat than orange but there was a confusion regarding yellow.
3 out of 12 users answered wrong when questioned if yellow was a bigger threat than orange or red. This could mean that personal experience or cultural differences could affect the perception of the threat level, thus orange would be the only color for the advisory level.

Illustration 36: The icon used in the final iteration

Finally, the ability of the system, assisting the driving experience received an average of 4.

Some data collected from the open-ended questions are worth mentioning.
For instance, one of the participants who is a new driver commented on the last question: "*The system is helpful for knowing what is happening in the back, for example when changing lanes, to see better if someone is on the road. It is helpful also for inexperienced drivers to help them estimate the distance and risk with other vehicles.*"

Another participant commented: "*I think it is very good because people do not notice everything while driving & may miss important information to take in and pay attention to. Perhaps when there are many cars the white lines could distract the driver slightly when he needs to watch the road. However once he gets used to it may be precessed in the subconscious. The warning and threat signs are great to warn of the dangers.*"

According to some of the participants, there are cases where this type of ADAS interface, could be even more helpful for the drivers. For instance, if this system was used for night driving, the information provided would be appreciated, since it is hard to notice some events, especially on the highway.

7. Discussion

7.1 Result Discussion

The user testing was implemented in order to have an insight about how the users perceive the design and also conclude on design elements in order to create the final iteration. Since the users were simply observing the system, it was not possible to “measure” distraction or situational awareness.

In order to test the intuitiveness of the design, the test participants were not provided with instructions. This was crucial in receiving proper results and the outcome was successful.

The users seemed to have difficulty distinguishing the icon on the advisory and warning level. An improvement has been implemented in the final iteration, using an outline on the icon but a further testing for this element was not possible. From the feedback received though, the users noticed that when the advisory or warning level was activated, the colour was enough for them in order to move their focus on the road.

In general, the open-ended questions of the questionnaire proved to be very useful since they revealed aspects that have not been considered by the team. For instance in the question regarding the ability of the system assisting the driving experience, one user mentioned that it would be helpful especially for inexperienced drivers and another one would find it helpful for night driving. This could lead for instance to consider this study a research base when designing a night vision assistant.

During the focus group one of the participants argued that the informative and the advisory warning in the front area of the car, are not important since the driver can see if there are obstacles in front of him. Our decision was to keep these levels in the front area since removing them would create inconsistency with the rest of the areas. It could also affect the user's trust in the system. Keeping the consistency was always taken into consideration.

However, the most important result of the focus group was minimizing the number of icons and keeping one simple icon for both pedestrians and bicyclists. Such a decision would help even more to acquire the information from the display with a few brief glances, decreasing the risk of a crash.

7.2 Process Discussion

Methodology and design iterations were tightly connected in this study, thus a detailed explanation of the requirement elicitation methods was provided on chapter 4, even if the main focus was on the design.
Traditionally the designers receive a list of the system and user requirements and that is the point when their part of the work begins.
While in this study, the designer was part of the whole process.
I believe that my participation and collaboration in the requirements elicitation and analysis was crucial, in order to gain a better understanding of the system and its requirements.
On the contrary, since my colleagues were involved deeper on the requirements gathering, their collaboration, input and feedback in the design phase was also important in order to achieve a good result.

The study highlighted the importance of the iterative design process.
The design evolved throughout the process, with input from the applied methods and evaluation. Including the users was also considered early and throughout the whole process. Almost every design iteration was evaluated, throughout focus groups and HMI expert testing in order to proceed to the next iterations. The team had to fulfil all the new requirements, while at the same time keep the design consistent and take the recommended HMI guidelines into consideration.

7.3 Future Work

How much users trust the system or if it they find the design distracting was not possible to test just by watching the system operating.
Calin Giubega & Peter Chen will implement a simulation study in order to test in more detail the functioning design.
One important aspect for the effectiveness of this UI design though is the glance time of the users in the display. If the users acquire more than two seconds in order to interpret the situation the design is not intuitive enough.
This could be a part of future work with the help of an eye tracking software.

8. Conclusion

The design of an ADAS user interface with the potential to enhance situational awareness has been presented in this report.
Making the driver aware of what is happening on the road, by only using visual modality and without increasing the driver's workload was a big challenge.

The process for implementing the final design, was iterative, including the users even in the early phases. The design was evolved in parallel with the requirements of the system which were modified during the application of different methods. The collected HMI design guidelines (section 3.6) were used as a guideline throughout the design process and assisted the implementation of the design.

Our consistent goal with the design was to keep the elements simple and intuitive in order to identify the situation by just a glance. The results of the user testing showed that the design was intuitive and that the elements such as icons and colours were effectively representing the system information.

Answering the research question

"How should an ADAS graded warning user interface visualize real-time road user information?"

The final iteration (Illustration 35) provides the answer to the research question. This visualization is the outcome of this thesis and reveals the design of an ADAS graded warning user interface which provides real-time road user information.
However, the iterative design process of this study, with the involvement of the designer in the requirement elicitation could possibly be applied not only on visual modalities, but it could also be used as a framework for similar studies with other types of modalities such as auditory or haptic.

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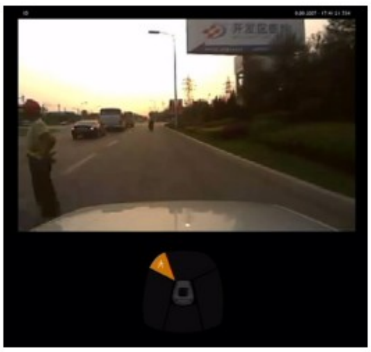
Appendices

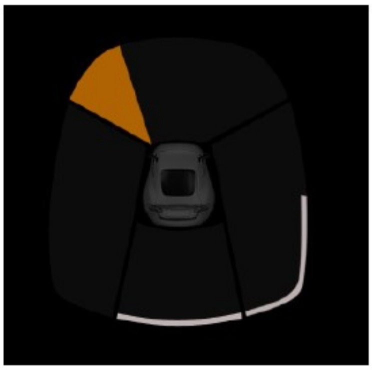
Appendix A: Pilot User Testing Questionnaire

In this screenshot how do you perceive the white lines?

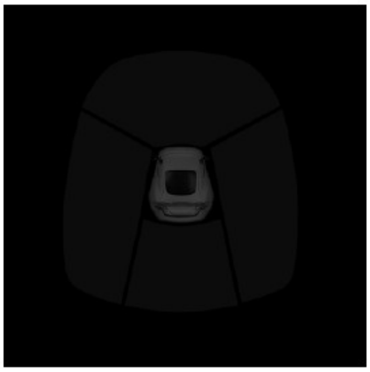
In this screenshot how do you perceive the orange color?

Is it easy to comprehend the situation in these two images by looking at the design?





Do you find something confusing in the design in general?



Is the shape easy to comprehend?

Appendix B: Final User Testing Questionnaire

(Note: Please fill in the information selecting one of the options or filling in text when required)

Part 1: General information

1. Gender:
   ☐ Male ☐ Female

2. Age: __________

3. Driving licence:
   ☐ Yes ☐ No

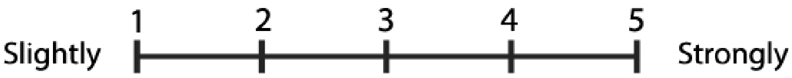
4. Year Obtained: __________

5. How often do you drive:

   ☐ Never ☐ Few days a year ☐ Few days a month
   ☐ Few days a week ☐ Almost every day

Part 2: Design evaluation

6. While you were watching the video, in what level did the gray lines manage to capture your attention, shown on the screenshot below.



For the same screenshot, how did you perceive the white lines? What do you believe they represent?

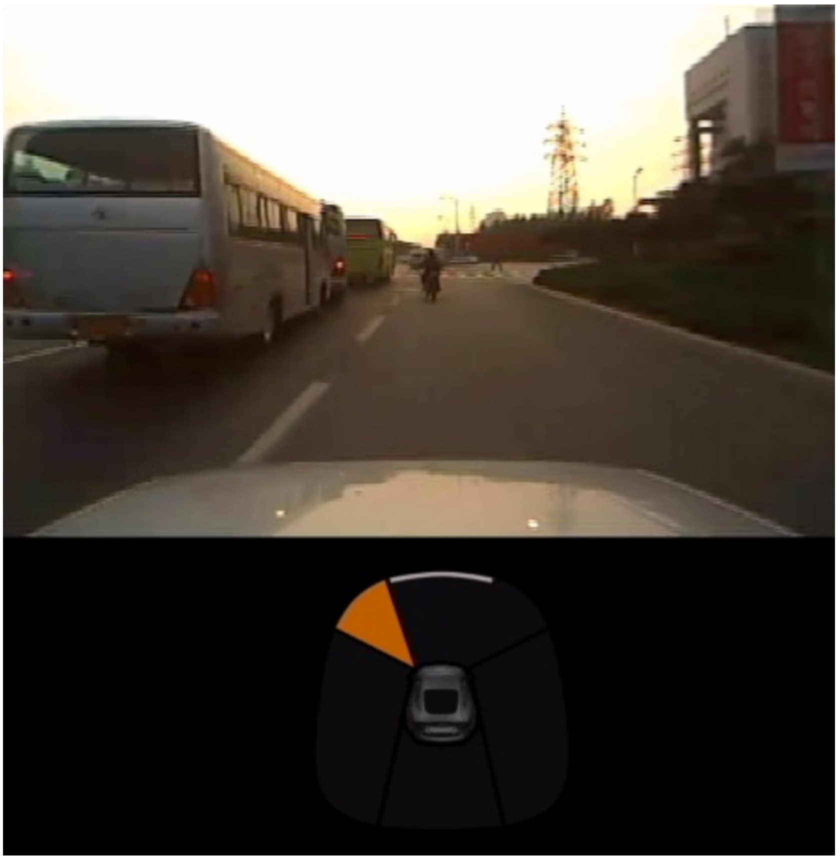
Answer: ____

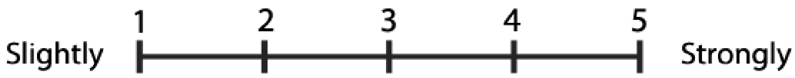
____

____

____

7. While you were watching the video, in what level did the orange section manage to capture your attention, shown on the screenshot below.





For the same screenshot, how did you perceive the white lines? What do you believe they represent?

Answer: ____

____

____

____

8. While you were watching the video, in what level did the red section manage to capture your attention, shown on the screenshot below.

Slightly 1 2 3 4 5 Strongly

For the same screenshot, how did you perceive the white lines? What do you believe they represent?

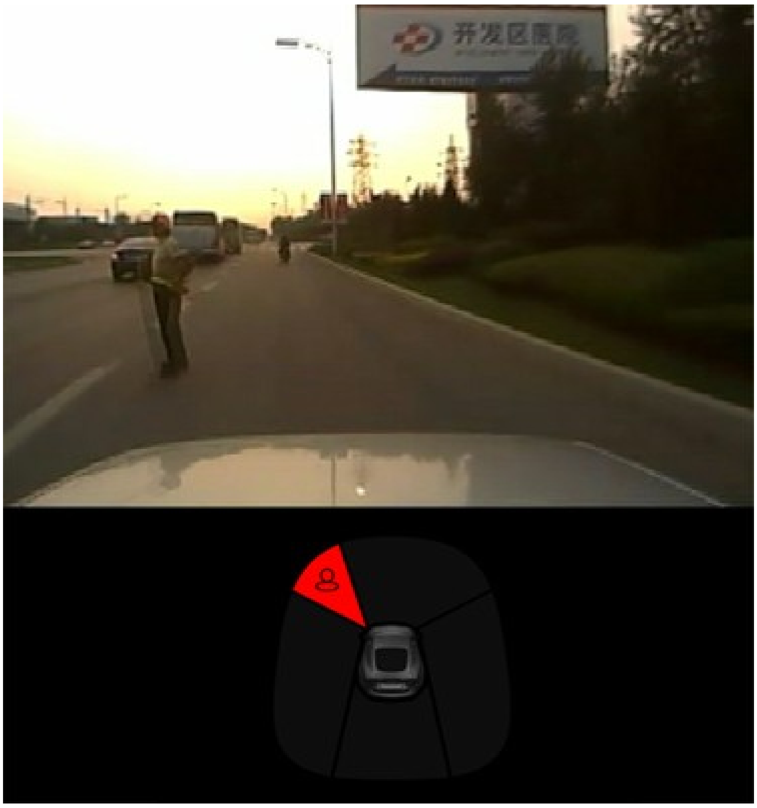
Answer: ____

____

____

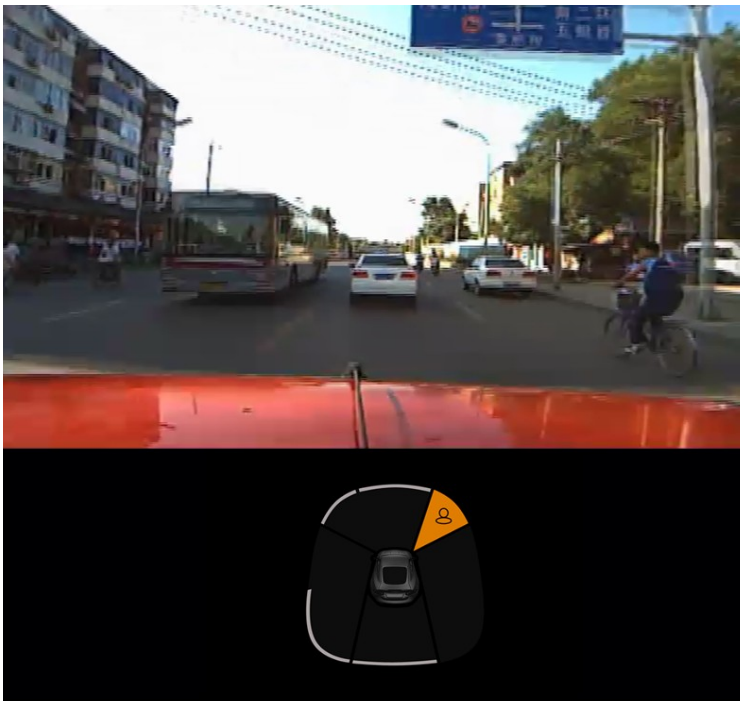
____

9. How effective was the design, in the screenshot below for distinguishing the vulnerable road users on the street?



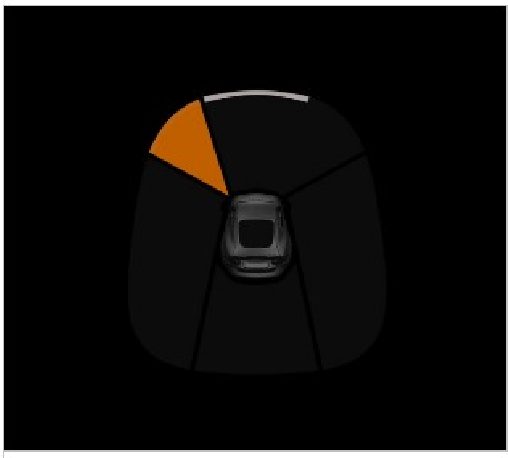
Slightly 1 2 3 4 5 Strongly

10. How effective was this icon in representing the vulnerable road users (pedestrians, cyclists)?

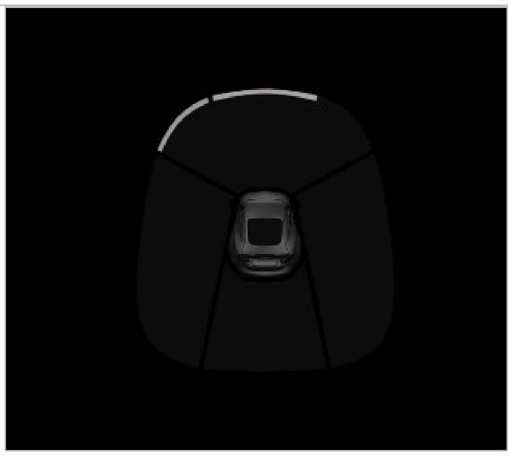


Slightly 1 2 3 4 5 Strongly

11. From the screenshots of the design shown below mark the one which in your opinion visualizes the higher level of threat on the front left section.

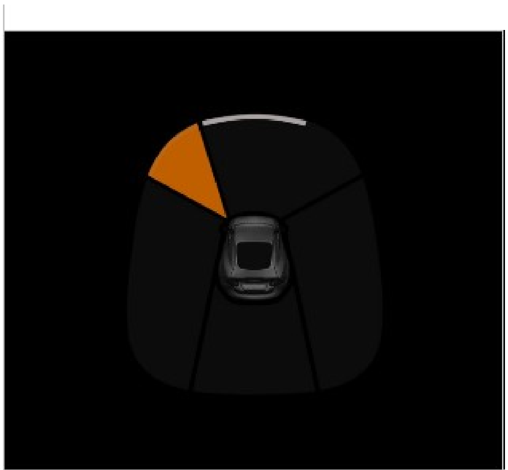


☐ a.

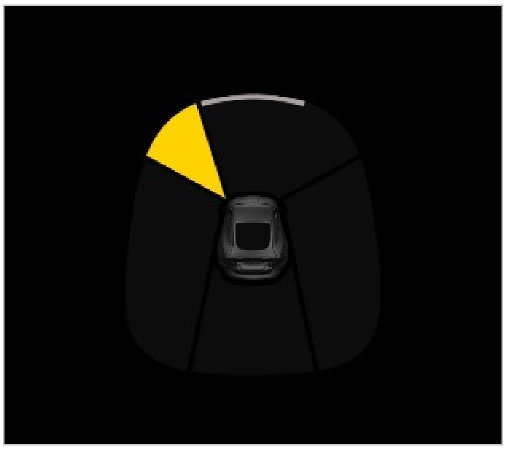


☐ b.

12. From the screenshots of the design shown below mark the one which in your opinion visualizes the higher level of threat on the front left section.

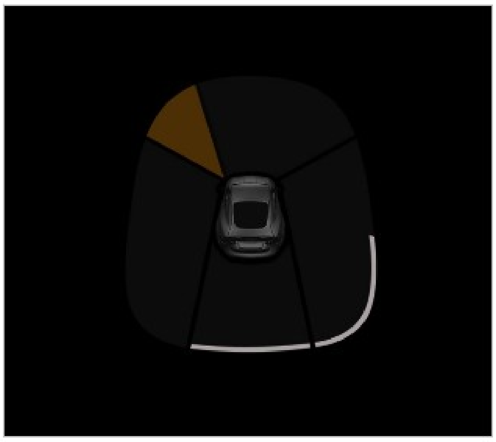


☐ a.

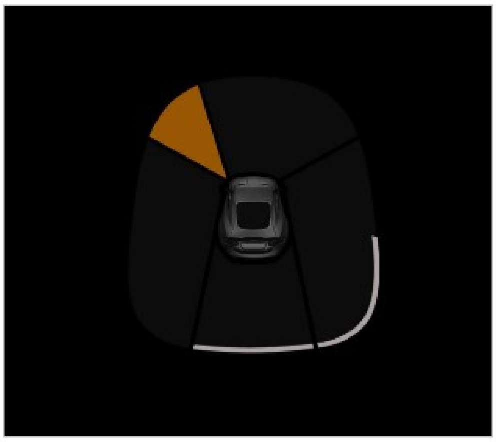


☐ b.

13. From the screenshots of the design shown below mark the one which in your opinion visualizes the higher level of threat on the front left section.

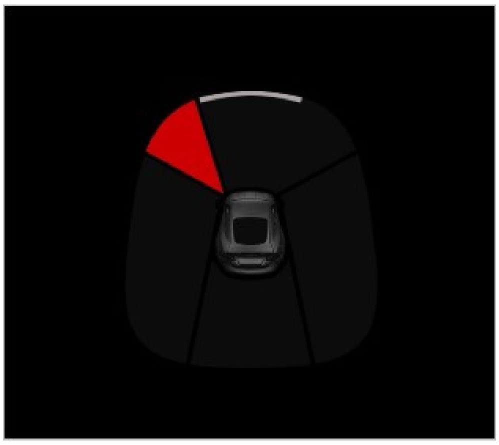


☐ a.

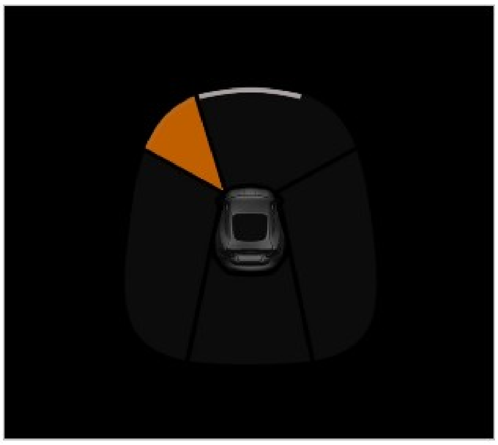


☐ b.

14. From the screenshots of the design shown below mark the one which in your opinion visualizes the higher level of threat on the front left section.

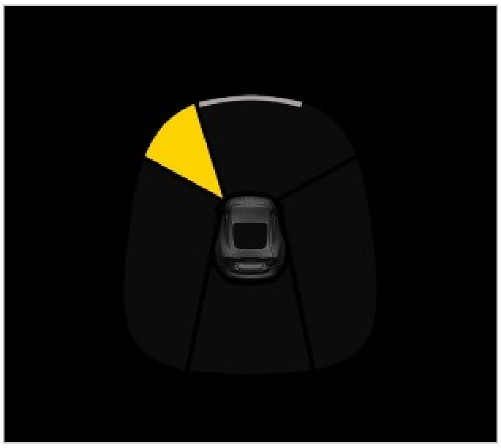


☐ a.

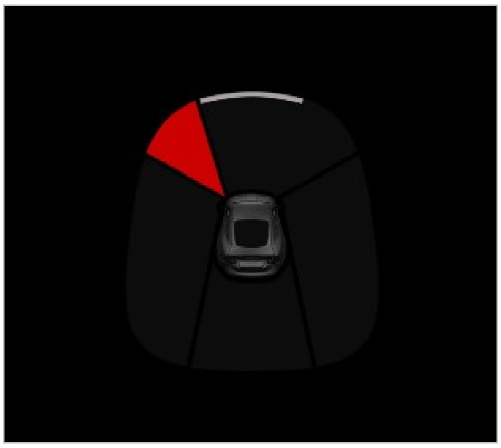


☐ b.

15. From the screenshots of the design shown below mark the one which in your opinion visualizes the higher level of threat on the front left section.



☐ a.



☐ b.

16. Do you believe such a system would enhance the driving experience? If yes in what degree?

☐ No

Slightly 1 — 2 — 3 — 4 — 5 Strongly

Thank you for your participation!!