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Is the driver ready to receive just car information in the windshield during manual and autonomous driving?

Dissertação elaborada com vista à obtenção do Grau de Mestre em:
Ergonomia – Factor Humano

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Resumo

A automação está a mudar o mundo. Como na aeronáutica, as empresas da indústria automóvel estão atualmente a desenvolver veículos autónomos. No entanto a autonomia do veículo não é completa, necessitando por vezes das ações do condutor. A forma como é feita a transição entre condução manual e autónoma e como mostrar esta informação de transição para o condutor constitui um desafio para a ergonomia. Novos ecrãs estão a ser estudados para facilitar estas transições. Este estudo usou um simulador de condução para investigar, se a informação em realidade aumentada pode influenciar positivamente a experiência do condutor durante a condução manual e autónoma. Compararam-se duas formas de apresentar a comunicação ao condutor. Um "conceito AR" mostrou toda a informação no para-brisas para ser mais fácil o condutor aceder à informação. O "conceito IC" mostrou a informação que aparece atualmente nos carros, usando o painel de instrumentos e o e-HUD. Os resultados indicam que a experiência do utilizador (UX) é influenciada pelos conceitos, sendo que o "conceito AR" teve uma melhor UX em todos os estados de transição. Em termos de confiança, os resultados revelaram também valores mais elevado para o "conceito AR". O tipo de conceito não influenciou nem o tempo nem o comportamento de retomar o controlo do carro. Em termos de situação consciente, o "conceito AR" deixa os condutores mais conscientes durante a disponibilidade e ativação da função. Este estudo traz implicações para as empresas que desenvolvem a próxima geração de ecrãs no mundo automóvel.

Palavras chave: Veículo autónomo; realidade aumentada; ecrãs; transições; fator humano; experiência de utilizador; situação consciente; aceitabilidade.

Abstract

Automation is changing the world. As in aviation, the car manufacturers are currently developing autonomous vehicles. However, the autonomy of that vehicles isn't complete, still being needed in certain moments the driver on ride. The way how is done this transition between manual and autonomous driving and how show this information to the driver is a challenge for Ergonomics. New displays are being studied to facilitate these transitions. This study used a driving simulator to investigates, whether augmented reality information can positively influence the user experience during manual and autonomous driving. Therefore, we compared two ways of present the communicate to the driver. The "AR concept" displays all the information in windshield to be easier to the driver access to the information. The "IC concept" displays the information that appears nowadays in the cars, where they use the Instrument Cluster and the e-HUD to display information. Results indicate that the user experience (UX) is influence by concepts, where "AR concept" had better UX in all the states. In terms of confidence, the results revealed higher scores in "AR concept" too. The type of concept does not influence the takeover times or the behavior of take control. In terms of situational awareness (SA), "AR concept" leave the drivers more aware during availability and activation. This study provides implications for automotive companies developing the next generation of car displays.

Keywords: Autonomous vehicle; augmented reality; displays; transition; human factors; user experience; situational awareness; acceptance

Abbreviations

ACC - Adaptative Cruise Control

AD – Autonomous driving

ADAS - Advanced driver assistance system

ADS – Autonomous driving system

AR – Augmented reality

BASt - German Federal Highway Research Institute

CC – Central Console

FCW - Forward collision warning systems

GB – Give back

GMB – Give me back

HMI – Human machine interface

HUD – Heads up display

IC – Instrument cluster

LKA – Lane keeping assistant

NHTSA – National highway traffic safety administration

OA – Operational area

REC – Rear end collision

SA – Situational awareness

SAE – Society automotive engineers

SW – Steering Wheel

TJ – Traffic Jam

UI – User interface

UX – User experience

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1. Introduction

Car driving is becoming automated to an ever-greater extent. It is prospected that the replacement of the human in monotonous driving situations or in day-to-day traffic situations by an automated system could reduce accidents, increase road safety, increase driver's comfort and reduce emissions. (Gold, Körber, Hohenberger, Lechner, & Bengler, 2015; Kuehn, Hummel, & Bende, 2009).

The continuing evolution of automotive technology aims to deliver even greater safety benefits and one day deliver Automated Driving Systems (ADS) that can handle the whole task of driving when we don't want to or can't do it ourselves (NHTSA, 2017).

The successful of autonomous driving is not only dependent upon an accurate and sophisticated automated function, but also by the adaption of the driver and society. One of the important aspects for a good adaptation of the driver, is related to the implementations of ergonomics in usability and user experience of the interfaces. The acceptance to the new technologies it depends of usability and user experience too, so in that sense, is very important a friendly display that can communicate the same language that the end users.

Recently, several car manufacturers proposed many developments and commercialization plans about head-up displays (HUD). This technology creates a new way for interactions between the driver and the vehicle (Phan, Thouvenin, & Frémont, 2016). In year 2012, 1.2 million vehicles worldwide were equipped with HUD and the world market will according to IHS Automotive forecast expand to 9.1 million vehicles in year 2020 (Boström & Ramström, 2014). With an expected growth of 758 percent in the next 8 years (IHS iSuppli, 2013) will put a great demand on the car manufacturers to supply new technical solutions and functionality together with new ways of user interaction design. However, the HUD bring other problems to the driver, so the augmented reality can be a way to solve that problems. The information projected in windshield can increase the acceptance, trust and awareness situation of the driver to the autonomous system, once the driver can see the same information that the autonomous car is perceiving.

Because all the reasons present above, in recent years, road vehicle automation and the augmented reality (HUD plus Augmented reality area) has become an important and popular topic for research and development in both academic and industrial spheres

(Boström & Ramström, 2014; Lorenz, Kerschbaum, & Schumann, 2014; Pauzie & Orfila, 2016).

The goal of the master thesis is to know if the drivers can beneficiate of the absence of instrument cluster in manual and autonomous mode, receiving only information in windshield. The answer to the previous problem should allow deliver guidelines to enhance the user experience about the information that we should show in HUD and in augmented reality area. Furthermore, these ideas and solutions should be aesthetically pleasing, have a functional benefit and help to strengthen in different manufactures.

2. Literature review

We have structured this literature review in the following way; first we explain the accident statistics to show the problem of the current cars in our lives. We then go to the driving task, as an introduction of what the autonomous vehicles should perform. We start with the automation concept and make a connection between automation and vehicles, where we describe the levels of automation, the transition between levels and the first introduction of the driver interacting with these vehicles. We then clarify what is consider human error in scientific accident analysis to clarify the high percentage of accidents associated to the human factor. Then we describe the driver factors influencing the performance in the transitions, as the trust, attention, awareness situation, user experience, among other. We then go the vehicle/environment variables that could influence that performance in the transitions, as the kind of road, interface, among others. After we describe in detail the displays, his characteristics, problems and the related work.

2.1.Accident statistics

For European Commision (2018) the road safety is a major societal issue. The National highway traffic safety administration (NHTSA) in USA, reported that in 2010, the cost per annum of automobile accidents amounted to $242 thousand millions (Kahn & Gotschall, 2015), an around 2.44 thousands people were harmed in vehicle accidents in USA (NHTSA, 2016) and over 1.2 million fatalities worldwide (Toroyan, 2009).

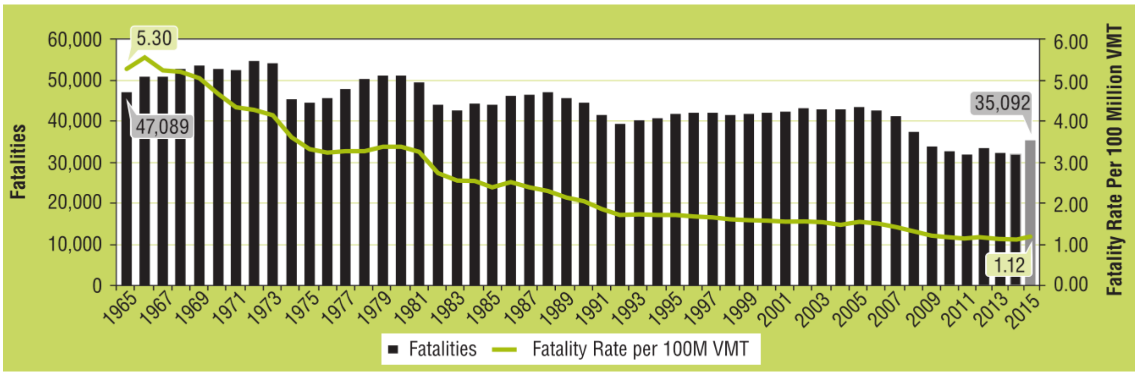
In USA, we can see on Graphic 1 that in 2015, aproximatly 35 thousand people died on road, where is the highest number since 2008 (NHTSA, 2016). In 2016, the number of deads on road because vehicle accidents inscrease to aproximatly 37 thousand in USA (NHTSA, 2017).

In Europe, according European Commision (2018), in 2011, more than 30 thousand people died on the roads. Statistics of 2015 showed that the countries that more contribute to the number of dieths on road in Europe were France, England and Italy, with more than 3 thousand deaths per country (Department for Transport, 2017). In Asia, the countries that more contributed were Japan and Republic of Korea with more than 4 thousand deaths per country (Department for Transport, 2017). Portugal had 593 road deaths in 2015 (Department for Transport, 2017).

We can see on Graphic 2 that the number of accidents in Europe are decreasing since 2001 until the current days according European Commision (2018), even so there was more than 26 thousand dieths in 2015.

A naturalistic study conducted in USA, the SHRP2 study, used online recorders about 1000 accidents on road, concluded that 90% of the crashes were due to human error[1] (Dingus et al., 2016).

The autonomous driving can have a key role concerning increase of road safety. According Pauzie and Amditis (2010), the interfaces, modes of dialogue, road environment and functional abilities of drivers are the key factor to the new intelligent driver support improve the road safety.



Graphic 1 - Road fatalities in Unites States of America since 1965 (NHTSA, 2016).

Graphic 2 - Road fatalities in the UE since 2001 (European Commision, 2018)

[1] In topic 2.4 is explained in detail what is considered human error to the classification of craches

2.2. Driving task

The driving activity is highly complex, where external (car, environment, road, among others) and internal factors (human) influence the driver performance. According Pauzie (2015), the reduced time to driver detect, understand the situation and react according, as well the full of unpredictable events are the reason to consider the driving highly complex.

Analyzing the driving activity, we can consider three primary driving tasks: (1) lateral control, (2) longitudinal control, and (3) monitoring, which are also present in the BASt[2], SAE[3], and NHTSA[4] definitions of levels of automated driving. Longitudinal control where is considered the starting, accelerating and stopping (McKnight & Adams, 1970). Lateral control where is included the steering, lane changing and curve driving (McKnight & Adams, 1970). Monitoring is the driver actions to complete with success the longitudinal and lateral control.

The most important in a driving situation is the driver keep the car in lane and has a safety distance to the car ahead. The perception of safety is subjective and depend the driver by driver.

According Merat and Jamson (2008) the driving situation is changing rapidly and moving towards more automation, where the driver's role is changing from being an operator to becoming more of a system supervisor.

2.3. Automation

According with the International Society of Automation (ISA, 2010) automation refers to "*the creation and application of technology to monitor and control the production and delivery of products and services*."

If we apply this definition to the driving, we can consider that the autonomous system will perform some or all the driving tasks. In intermediate levels of automation[5], the autonomous vehicles systems allow the driver and the autonomous system share the management of the car. If we think in the example of Tesla autopilot already in market (Ex: Tesla Model S), in manual driving (level 0 of automation; SAE (2016)) all sensing and control is carried out by the human, however in autonomous mode (level 2 of

[2] BASt - German Federal Highway Research Institute
[3] SAE – Society of Automotive Engineers
[4] NHTSA - US National Highway Traffic Safety Administration
[5] Explained in detail in topic 2.3.2

automation; SAE, 2016), the drivers and their automated driving systems actively cooperate to achieve the primary task of driving, where in some moments the driver is only looking to the road. According Louw (2017), looking from the driver's perspective, a new role is associated to the driver, the supervisor, that is, the driver give instructions to the autonomous function, however the car control is done by autonomous function. The automated system creates substantive human factors challenges that need to be addressed. According Llaneras, Salinger and Green (2013) some factors of the adaptation to automation are afecting the driver capabilities (eg: workload, processing of information or awareness situation), as the misunderstanding, misuse, over-reliance on the system, changes in attention and distraction from driving task[6].

Consequence of this adaptation to automation already provoked four fatal accidents when autopilot was activated (level 2 of automation; SAE, 2016), three in USA and one in China. One of these accidents (UBER accident, in USA), who death was a pedestrian. In 2016, there was the first die in an autonomous car accident, Joshua Brown, when his Tesla model S crashed against a 18-wheel tractor-trailer, in Florida (USA), because the sensors of his car failed to distinguish a white tractor-trailer crossing the highway against a bright sky (Tynan & Yadron, 2016). According Banks, Plant and Stanton (2018) the NHTSA found that the driver was too reliant on Tesla autopilot function and that the car asks the driver 7 times to put his hands on the wheel. They conclude that was a "designer error" the main reason to the accident. In the same year, in China, other fatal accident happen with a Tesla during the transition from manual to autonomous driving (Level 2 of automation; SAE, 2016). Two years later (2018), new fatal accident happen in USA, with "autopilot" function activate, where a Tesla model X hit a barrier at the center of the highway (Barnes, 2018). This accident occurs in the fourth time in "autopilot" mode during that fatal trip and the last visual and audio warning happen 15 minutes before the collision (Barnes, 2018). In the two accidents with "Autopilot" function activated (level 2 of automation; SAE, 2016) reported in this thesis, it's visible the automation problems present (over-trust and misuse), highlighting the importance of the displays to solve/minimize these problems.

[6] This automation problems are described in detail in topic 2.5

2.3.1. Automated driving

Different names have been associated with "autonomous driving" as "driverless" (eg: Merat, Jamson, Lai, Daly, & Carsten, 2014) or "self-driving" (eg: Sivak & Schoettle, 2015). In this thesis, we used the name of "Autonomous driving" to describe the autonomous system in car.

The idea of autonomous vehicles is almost 75 years old (Kornhauser, 2013) and was included in General Motors' vision of the future at the 1939 New York World's Fair (Geddes, 1940). However, the first projects (1980, 1990) related with autonomous driving focused on developing the hardware and software capabilities. More recently, there have been a number of projects that have focused on the human factors issues related to vehicle automation, while also implementing and evaluating automated functions in vehicles (eg: CityMobil; Toffetti et al., 2009).

According Ekman and Johansson (2015), the near future is expecting new systems as the autonomous vehicles. In a study of Ross (2016), the results showed that Tesla Autopilot (autonomous driving level 2; SAE, 2016) maintains its distance to the lane center more consistently than manual drivers. According with Kalra and Paddock (2016) the autonomous driving is the key factor associated with the reducing of accidents on road. Kahn and Gotschall (2015) pointed that these new cars can reduce the societal costs (eg: medical, legal, services and congestion costs).

Nowadays, most car manufacturers have released cars that are equipped with level 1 of automation (SAE, 2016), as the adaptive cruise control (ACC[7]) and/or lane keeping assistance (LKA[8]) systems (Lu, Happee, Cabrall, Kyriakidis, & de Winter, 2016), where by definition, when the driver activates both at the same time is considered level 2 of automation (eg: Tesla autopilot).

In 2040, according the IEEE[9] (2014), is expected the autonomous vehicles will account for up to 75% of vehicles on the road. It's necessary time to the drivers accept this new technology, so a hard way is necessary in this field during the next years (Noy, Shinar, & Horrey, 2017).

[7] Technology that assist the driver task longitudinal.
[8] Technology that assist the driver task lateral.
[9] Institute of Electrical and Electronics Engineers

Autonomous cars will give to the drivers the opportunity to enjoy the time in traffic, improve the congestions on road, reduce motor crashes, deaths on road, injuries, and become the travel on car more accessible for everyone (Casner, Hutchins, & Norman, 2016). According Pauzie and Orfila (2016), the main objective of the autonomous vehicles concerning to road safety is “zero accident” perspective.

2.3.2. Levels of automation

In the last years, several attempts have been made to create taxonomies in autonomous vehicles. Three authorities, mainly the German Federal Highway Research Institute (BASt; Gasser, & Westhoff, 2012), the Society of Automotive Engineers (SAE, 2016), and the National Highway Traffic Safety Administration (NHTSA, 2013) have defined classifications about the automated driving systems from driver assistance to full automation.

They are similar in many aspects, where the NHTSA and SAE defined the levels of automation in base on the driving task (explained in topic 2.2), if is performed by driver or automation. The increase of level, means a shifting in the driver role from primary controller to a supervisor.

The taxonomy created by SAE to automation in vehicles with 6 levels of automation (level 0 to level 5) have become the most widely cited, and to standardize and aid clarity and consistency. The U.S. Department of Transportation (2016) adopted the updated SAE (2016) level of automation definitions in their safety vision for automated vehicles. For these reasons, this thesis will adopt the SAE (2016) nomenclature as reference.

SAE International’s standard J3016 (SAE, 2016) defines six levels of automation for automakers, suppliers, and policymakers to use to classify a system’s sophistication (Figure 1):

Level 0 – This level is known by “No automation” (SAE, 2016): At this level, the driver performs all driving tasks like steering, braking, accelerating or slowing down. It’s the level that all the drivers are used to it, the manual driving;

Level 1 – This level is known by “Driving assistance” (SAE, 2016): At this level, the vehicle can assist the human driver with an advanced driver assistance system (ADAS), for example steering or braking/accelerating, but not both simultaneously. The driver has full responsibility for monitoring the road and taking over if the assistance system fails to act appropriately. Example of ADAS are the Adaptative Cruise Control (ACC) or the Lane keeping assistant;

Level 2 - This level is known by "Partial automation" (SAE, 2016): At this level, an advanced driver assistance system (ADAS) on the vehicle can itself actually control both steering and braking/accelerating simultaneously under some circumstances. The driver must always be ready to take control of the vehicle and it still responsible for most safety-critical functions and all monitoring of the environment. Most automakers are currently developing vehicles at this level, where the vehicle can assist with steering and acceleration functions and allow the driver to disengage some moments of their tasks. It's the first level where the car can manage by itself some conditions of the environment without the driver, but it's mandatory the driver maintains the hands on the Steering Wheel (SW). Some examples of brands with this level are: Audi Traffic Jam Asssist, Cadillac Super Cruise, Mercedes-Benz Driver Assistance System, Tesla autopilot and Volvo Pilot Assist (Car and Driver, 2017);

Level 3 - This level is known by "Conditional automation" (SAE, 2016): At this level, an autonomous driving system on the vehicle can itself perform all aspects of the driving task under some circumstances defined by car, as for example in highway, speed under 60 km/h. In those circumstances, the human driver must be ready to take back control at any time when the autonomous driving system requests the human driver to do so. The car send a prompt when can't manage something. The biggest leap from Level 2 to Levels 3 is the time to take control, that is, in level 2 is 0 seconds and in level 3 is 10 seconds. The driver's attention is still critical at this level, but can disengage from "safety critical" functions like braking and leave it to the technology when conditions are safe. It's possible make secondary tasks during this level. A example of system with this level is the Audi Traffic Jam Pilot (Car and Driver, 2017). This level represents the maximal level tested in this study.

Level 4 - This level is known by "High automation" (SAE, 2016): At this level, the autonomous vehicle can itself perform all driving tasks and monitor the driving environment. In some contexts (eg: highway with normal weather), the car can perform all the driving, where the driver attention isn't necessart. At Levels 4 and 5, the vehicle is capable of perform the longitudinal and lateral control, as well as the driving monitoring. The car has the capacity to answer to unpredictable events, determining when to change lanes, turn, and use blinkers. At Level 4, the autonomous driving system would first notify the driver when conditions are safe, and only then does the driver switch the vehicle into this mode.The difference between level 3 and level 4 is the time to take control. In level 4 the car can ask the driver control later. A example of system with this level is Firefly, that is a prototipe created by google (Car and Driver, 2017);

Level 5 - This level is known by “Full automation” (SAE, 2016): At this level, the autonomous vehicle can do all the driving in all circumstances. The driver has the role of the passengers and never need be involved in driving. This level of autonomous driving requires absolutely no human attention. Driver does not need to use pedals, brakes, or a steering wheel, as the autonomous vehicle system controls all critical tasks and monitoring of the environment. The driver only need to introduce the destination before start the travell. A example of system with this level is Waymo, a prototipe createed by google (Car and Driver, 2017).

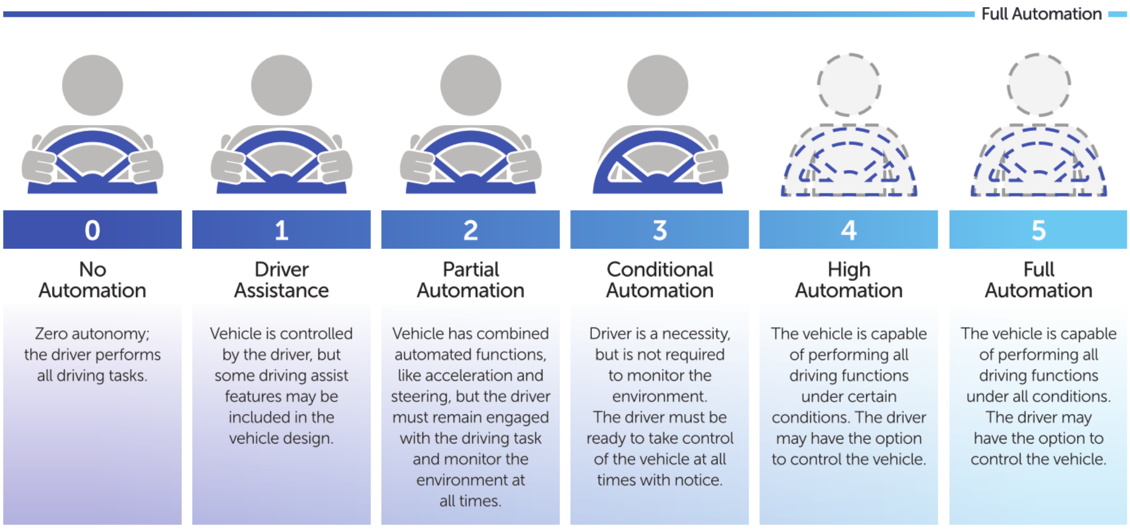


Figure 1 - Description of levels of driving automation by SAE (source: https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety)

2.3.3. Transition of control

Regarding vehicle automation, the term "transition" has been used in the literature to refer to either the activation or deactivation of an automated driving function (Gold, Damböck, Lorenz, & Bengler, 2013; Miller, Sun, & Ju, 2014; Nilsson, Falcone, & Vinter, 2015; Pauwelussen & Feenstra, 2011; Toffetti et al., 2009), a change in the level of automation (Merat et al., 2014; Varotto, Hoogendoorn, Arem, & Hoogendoorn, 2015; Willemsen, Stuiver, Hogema, Kroon, & Sukumar, 2014), a transfer of responsibility (Saffarian, de Winter, & Happee, 2012), or the period between the changing from one vehicle control state to another (Flemisch et al., 2012). In this thesis, the transition is defined as, the change of function state, according Gold et al. (2013).

Transition from manual to autonomous driving is initiated by driver, normally with a button, however the transition from autonomous to manual can be initiated by the driver or automation that will request the driver control. In this thesis, we focused in the transition from level 0 (SAE, 2016) to level 3 (SAE, 2016) and the reverse. A detailed description of all the possibilities are presented in topic 4.2.

Two issues with transitions have consequences to driver safety. The transition from manual to autonomous has the problem of the driver think that autonomous driving function is activated after press the button that activate the autonomous driving function, and normally the driver takes hands off the steering wheel quickly, whereas can there be situations where some problem with the button don't leave the function to be activated correctly. It's very important in this moment an interface that is clear to the driver, leaving no doubts about the function state. The other transition, autonomous to manual mode is where most of the researchers have focused (eg: Gold et al., 2013; Lorenz et al., 2014). The main problem is the driver resume the control when is in autonomous during long periods, phenomenon known by the driver stay "out of loop" [10] (when the driver isn't aware of the vehicle state and surrounding) and engage in manual driving again. Previous research on the safety of transitions in this level has focused on assuring that the driver is aware of the transition (eg: Nilsson et al., 2015).

2.3.4. Human-automation interaction

Most of the studies about human-automation interaction are in aviation. Earlier human factors research in the field of automation indicates that the automation improve the precision and variability of human task performance, but also new problems are being created by automation related with safety (Lu et al., 2016). As seen in the aviation sphere, the greater is the automation, greater is the risk of degraded performance in the return to manual control (Endsley & Kiris, 1995). A meta-analysis investigated the impact of degrees of automation on human performance and concluded that when the degree of automation moves across the critical boundary from information acquisition and analysis to selecting or execute a specific action the humans are more vulnerable to automation "failures" (Onnasch, Wickens, Manzey, & Li, 2013). However, these studies were

[10] Explained in detail in topic 2.5.5

performed in aviation context, so we don’t know if these results have relationship with autonomous vehicle.

Merat and Jamson (2008) argued that is very important help the drivers to keep “in-the-loop”, mainly in high levels of autonomous driving, where they recommend decision and action selection of driver as well as action implementation. This argument isn’t according to full autonomous driving (level 5; SAE, 2016), once that the automation perform the driving task without ask the driver to resume the control in any moment, so the driver can stay always “out-of-loop”.

Also, classical vigilance studies (Mackworth, 1950) have shown that it is virtually impossible for an individual to maintain constant attention towards a source of information that does not often change, to monitor for any system changes, requests, or errors (Bainbridge, 1982). It’s very important understand how the information should be displayed to the driver, to prevent interaction errors and accidents, field where the research of human-automation interaction has increased. In aviation, automated system like the forward collision warning systems (FCW), that assume some control over the aircraft have created challenges regarding the interaction between human and automation in general, not only regarding incorrect mental modes and mode confusion of the automated systems (Louw, 2017). This autonomous systems with low level of automation doesn’t necessarily reduced the human workload, but allocate this workload in other tasks, as the monitoring the system for errors (Parasuraman, Mouloua, Molloy, & Hilburn, 1996). Routine in-fight operations, where the workload is low, showed to degrade the pilot monitoring behavior (Sumwalt, Thomas, & Dismukes, 2002). This problem have more impact when the pilot needs manage the task with 100% attention again, due to a time-critical situation, such as during the descent approach to land (Louw, 2017). The degrade of the pilot monitoring can have a big impact in the autonomous vehicles too, when the car ask the driver control or reaches s system limit.

Research of Wiener (1988) in aviation context, has shown that how much more frequent and longer is the time of the pilot using automation, the more impaired their manual flight skills become.

In the domain of automated driving, the intermediate levels are what is expected more problems, once that the human has to monitor the automated system and may be particularity dangerous because the human is a bad supervisor, where they are unable to remain vigilant for long periods of time (Casner et al., 2016; D. A. Norman, 2015). The change of the driver's role in automated vehicles make clear that the human factors should be careful studied by researchers, police makers and designers (Merat & Lee, 2012).

In summary, some problems can be identified by the interaction between human and automation, as over and under reliance because of an wrong mental model (Saffarian et al., 2012), loss of skill, loss of situation awareness and quick changes in mental workload or too much or too little workload (Merat & Jamson, 2009; Toffetti et al., 2009). The lack of feedback when the driver is "out of the loop" during autonomous driving can have a huge impact in these problems, mainly because may be difficult to the driver understand when is necessary act in these systems, called mode-confusion (Hoc, 2000; (Ekman & Johansson, 2015). The limitations of automation should be well perceived in detail because these automated systems may not operate according driver expectations and for consequence provoke interaction problems (Saffarian et al., 2012).

2.4. Driver error does not mean driver culpability

The scientific crash analysis attribute to human error all the accidents that there is no evidence of some problem in the vehicle or infrastructure (Noy et al., 2017). For that reason, when we try to understand the main guilty by accidents on road we found the human error in the first position with 90% (Dingus et al., 2016). Driver factors, as the fatigue, distraction or falling asleep have been associated with crashes from less than 5% to nearly 40% (Shinar, 2017). We can conclude with this difference of data that many crashes are difficult to the driver to prevent. When we try to understand the reasons behind a crash associated to a human error, we should have a macro vision, that is, thing about the characteristics of road thaw allow the driver fail, the signals, the car design, the weather conditions and don't look only to the driver that had an accident because did a bad read of the situation.

The automation has an important role helping the drivers to solve problems, as the sensing, decision-making and vehicle control (Noy et al., 2017). It's important consider that the automation didn't solve possible violations of the drivers, so crash analysis attribute to human error will certainly continue.

2.5. Driver-based factors influencing performance in the transition

There is a range of factors contributing to the performance in the automation as was explained in topic 2.3.4. We will describe in this topic in more detail these factors, that are: Mental models, trust, attention, awareness situation, the out-of-the-loop problem, the complacency and automation bias, as well as the usability and user experience.

2.5.1. Mental models

For an effective control over any process, the operator must possess a mental model of that system (Moray, 1990). We develop these mental models of things and people as a result of our experiences and culture (Galitz, 2008). The internal representations of what we understand of something is considered a mental model (Galitz, 2008). Normally, it's complicate a person describe these mental models and often is unware it even exists (Galitz, 2008). There is a progressively developed of these mental models in order to interact with other person, do something, make decisions or understand something (Galitz, 2008).

The intermediate levels of automated systems, where the vehicle and the system share responsibilities, the mental models are primordially important. It's the driver's mental model that will guide in the decision of intervene in particular moments (Louw, 2017). The automated system and the driver should share a consistent mental model, if not the driver may either intervene worse or unnecessary, or simply not intervene when is necessary (Pauwelussen & Feenstra, 2011). The new systems should consider that the drivers already have their preconceptions and expectations in their mental models of driving (Galitz, 2008). If the autonomous vehicles conform to the mental models of driver has developed, by consequence the model is reinforced and the system use will seem more intuitive (Galitz, 2008). If the system doesn't consider the driver mental models, problems in learning to use the system will be encountered. The design has a key role in the driver's mental models, once that the information should be recognized and understood.

In summary, the mental models in automated systems will have a vital role in drivers' problem solving, decision making, judgement and abilities to plan and act, during their interactions (Beggiato & Krems, 2013). It is extreme importance, therefore, that drivers can develop appropriate models of the system's functionalities to intervene when is necessary (Sarter & Woods, 1991).

2.5.2. Trust

Automation trust can be defined as "*the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability*" (Lee & See, 2004). In one of the most comprehensive reviews of trust in automation, Lee and See

(2004) assumed that trust is a mediating factor between the operator's intention to use or rely on the automation and beliefs about the characteristics of automation. In consequence, the trust has an important role to the success of human-automation interaction (Lee & See, 2004). However, it is very important the automated system develop appropriates levels of trust in the driver, if not may lead to over trust or distrust, and by consequence lead to misuse or disuse, compromising safety (Parasuraman & Riley, 1997).

Lee and See (2004), in their dynamic model of automation trust and reliance, propose that trust is formed through a dynamic interaction between the automation, interface, operator and context. This interaction between elements is guided by three important elements: 1) The trust and reliance are part of a closed-loop feedback process, where the reliance is who guide the driver to trust in automation and that trust is who guide the user's reliance. 2) The context of user, as the user workload or effort to engage, has a key role in the trust translation into actual reliance. 3) The way how the users interpret the information about the automation is highly influenced by developing appropriate trust. According Lee and See (2004) model we can conclude that the content and format of information displays are crucial to calibrating trust.

In autonomous driving, high or inappropriate levels of trust may lead drivers to utilize systems incorrectly, under conditions they are not designed for, or fail to adequately monitor the road environment while the systems are engaged (Noy et al., 2017). This variable in automated systems driving have been investigated in simulation and experimental studies (eg: Helldin & Riveiro, 2013). Trust is usually evaluated through questionnaires before and after experience of driving (Pauzie & Orfila, 2016).

2.5.3. Attention

Attention can be defined as a process which allow the human to select and process the large amount of information our sense organs receive (Wolfe et al., 2012). We can divide attention in external and internal. As the name indicate, internal attention refers to internal information that we select and manipulate, such as the contents of working memory, response selection and long term memory (Chun, Golomb, & Turk-browne, 2016). External attention is the selection and modulation of sensory information that enters in our sensory organs (McDonald, 2016). The human attention is attract easily when an object differs on the environment than when the object is similar with the environment

(McDonald, 2016). The human attention process is limited, once that sometimes there is more information than we can process (Chun et al., 2016), and the driving environment is a good example of that. According Chun and colleagues (2016), the objective of the attention is to direct mental resources to specific objects in the environment. In driving context, monitor and located specific targets, the human divide his/her attention in several areas of interest (McDonald, 2016). An area of interest is defined as *"a specific area where task related information can be found"* (Wickens, Christopher D., Hollands, Justin G., Parasuraman, 2013). An example of area of interest in vehicle is when the driver want to see the current speed in Instrument cluster or in heads up display.

When the human attention is directed to a specific object in the environment, two different ways can be associated, the endogenously or exogenously way and this change of attention to the object can be automatic or controlled (McDonald, 2016).

Exogenous process occurs mainly in unfamiliar environment, as a result of the stimuli presented to the human rather than his/her objectives and plans (Theeuwes, 1994). Endogenous selection occurs when people have knowledge of the environment and specific goals in the environment (Theeuwes, 1994). For example, an expert driver to automated systems already know where appears the information about the function in the displays, so his/her attention occurs by endogenous process. In consequence, endogenous process is quickly comparatively to exogenous process, and normally more effectively (Trick, Enns, Mills, & Vavrik, 2004).

Change of attention is characterized by "automatic" process when the human repeatedly executes a task many times. This selection of attention is quick, effortless, unconscious, without awareness and is difficult to stop or modify once it is initiated (McDonald, 2016). According Castro (2005), "controlled" processing can be stopped, started or modified, however it is difficult to execute multiple controlled processes at once.

There are 4 types of attention control in driving, that are: reflex (exogenous and automatic), habit (endogenous and automatic), exploration (exogenous and controlled) and deliberation (endogenous and controlled). An example of "reflexive selection" are the brake lights in cars, where the color only appears when the driver press the brake pedal, and that is more effective at capturing attention and help the driver in the car behind to stop quickly than brake lights which are constantly illuminated (Berg, Berglund, Strang, & Baum, 2007). An example of "habitual selection" is an exit in highway to drivers without experience of driving in this kind of roads, where he/she has the goal of leave the highway in the next exit, habitually deploy attention to the right side of the road in search of an exit indication sign (McDonald, 2016). Relatively to “selection by exploration” is when a driver may choose to explore their environment because their believes that the driving demands are low (Trick et al., 2004). An example of “Selection by deliberation” in when the driver already know that the autonomous function is almost available to the activation, and the driver is looking to a specific place of the display to get that information.

2.5.4. Situation awareness

Situation awareness (SA) is considered one of the most important variables in the field of human factors as influencing the performance and safety (Parasuraman & Manzey, 2010).

Several efforts have been made to develop a concise definition of SA, with Endsley (1988) being the most commonly cited:

"Situation 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."

Endsley (1995b) divide the definition of SA in 3 levels, where the perception of relevant elements in the environment we associate with level 1 of SA, the comprehension of what these elements or the combination of elements mean with level 2 of SA and using this information to predict the status of the environment in the near future we associate with level 3 of SA, while keeping a goal in mind. The levels of SA are hierarchically dependent, which means, if the driver doesn’t perceive well the elements in the environment (level 1 SA), will result in inaccurate meaning/sense making and prediction (Level 3 SA; Ward, 2000).

Making a connection between driving and levels of SA:

In level 1 we can include the other cars, traffic signs, the road, warning lights and driving information on the instrument cluster as well as their status. In level 2, this is based on the elements of the first level, where the driver try understand the mean of each element and their relevance to current situation in relation to the subject’s goals (Endsley, 1995b). In level 3, according to Endsley (1995) is the “projection of future status”. This is the highest level of SA and is the ability to predict future behavior of elements in one's environment, combining level one and two.

Fletcher (2008) assumes that the humans are highly adaptable, able to solve complex problems, and have a superior sensory system, making them highly capable drivers that can to solve effectively problems during driving. The SA plays an important role to the driver fulfil these competencies. Many factors can influence the drivers' SA during critical events, as the time budget[11], the road[12], traffic scenario and how display the visual information to the driver [13] (Louw, 2017).

Bainbridge (1983) argued that the automation is likely to reduce the driver's SA, because the human seems to be ill suited to supervise tasks. In a critical review of the literature, (De Winter, Happee, Martens, & Stanton, 2014) argued that there is a close link between SA and high autonomous driving, based on studies of drivers' eye movements. However, new technology in vehicles has created new possibilities for drivers' SA to be improved, as heads up displays that project the information in windshield, so the driver may be stay less distracted with these displays (McDonald, 2016).

2.5.5. The out-of-the-loop problem

Automation also changes the form and the quality of the feedback (Endsley & Kaber, 1999). A key factor contributing to the automation problems is the "out-of-the-loop" performance problem. According to Kelsch, Bengler, Kienle, Flemisch, & Damböck, (2009), a driver is considered out-of-the-loop when they are "*not immediately aware of the vehicle and the road traffic situation because they are not actively monitoring, making decisions or providing input to the driving task*". So, out-of-the-loop refers to a state where an operator loses awareness of the system state and external situation due to limited human-system interaction (Endsley & Kiris, 1995). This is characterized by a reduced ability of a driver to resume the car control and driving in manual driving again. In this sense, SA focus in the state of the other elements in the environment and "out-of-the-loop" focus in the state of the system, however, these are not mutually exclusive (Louw, 2017). How the humans are bad supervisors, is difficult to detect efficiently system errors (Parasuraman & Riley, 1997). Display information in windshield may help the drivers to solve these problems. Parasuraman and Manzey (2010) argued that the human tendency

[11] Explain in detail in topic 2.6.1
[12] Explain in detail in topic 2.6.3
[13] Explain in detail in topic 2.6.2

is direct his/her attention to the manual tasks and reduce his/her level of monitoring in highly-reliable automated systems.

Also, in the event of an automation failure, the time it would take to re-orient an out-of-the-loop operator to both the system state and the task at hand would most likely result in either a diminished effectiveness of the task or even a total failure to complete the task (Endsley & Kaber, 1999). We can conclude that if the problem of a driver “out-of-the-loop” not controlled, it will have a huge impact in the consequences of automation-human interaction. However, “out of the loop” problem doesn’t integrate aspects related to automation-induced complacency and automation bias, which plays a key role in the development (Parasuraman & Manzey, 2010) and is explain in the next topic.

2.5.6. Complacency and automation bias

Parasuraman and Manzey (2010) defined complacency as “*poorer detection of system malfunctions under automation control compared with manual control*”. From this definition, we can assume that complacency is, for example, when the driver is in autonomous driving and in that moment, he gives more importance to the mobile phone than to a possible failure of automation. This complacency to autonomous driving can increase with previous experience where everything worked in a good way. So, we can conclude that how much experience with autonomous driving, more the risk of complacency.

Parasuraman and Manzey (2010) describe automation bias as the “*omission or commission errors made by operators, essentially a tendency towards over-reliance on automation*”. An example of “omission” from everyday experience is a driver who misses the correct exit from a highway because the navigation aid failed to notify the driver (Parasuraman & Manzey, 2010). An example of “*commission*” is a driver who falsely enters a one-way street from the wrong side because the navigation aid (which may not have had the one-way information in its database) tells the driver to do so (Parasuraman & Manzey, 2010). Dzindolet, Beck, Pierce and Dawe (2001) assumed that three main factors have been assumed to contribute to the occurrence of automation bias: 1) The human is the tendency to choose the road of least cognitive effort in decision making. 2) The humans consider the automated aids as powerful agents with superior analysis capability (Lee & See, 2004). 3) The human prefers the diffusion of responsibility (Parasuraman & Manzey, 2010).

2.5.7. Usability

The concept of usability according to ISO 9241-11:2018, specifically, Part 11: "Usability definitions and concepts". Usability in this standard is defined as "*The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*" (ISO, 2018).

Create a system effective is important to design clear and intuitive displays (Hancock et al., 2013) as well as making it easy to use or focus on training the driver in order to create an expert understanding of the system characteristics (Lee & See, 2004). According Nielsen (2003), when something is difficult to use, when isn't clear what you can do, when the users get lost, when the information is hard to read, the people leave the product. The information presented by the system through the interface should be presented in a way that is easy for the user to comprehend (Ekman & Johansson, 2015). An important factor to achieve this is to have concrete and preferably detailed information with a constant and structured appearance (Lee & See, 2004). Factors such as simplicity, balance, intuitiveness, structured and detailed information should be considered when designing a human-machine interaction system that is optimal for the user and in this case the driver (Ekman & Johansson, 2015). The usability should be studying applying user testing and it plays a role in each state of the design process (Nielsen, 2003).

2.5.8. User experience

User Experience (UX) is about a user's behavior, emotions and attitudes towards a product. The concept of user experience according to ISO 9241-11:2018, specifically, Part 11: "Usability definitions and concepts". User experience in this standard is defined as "*user's perceptions and responses that result from the use and/or anticipated use of a system, product or service*" (ISO, 2018).

The users' perceptions and responses include the users' emotions, beliefs, preferences, perceptions, comfort, behaviors, and accomplishments that occur before, during and after use (ISO, 2018). The user experience is a consequence of brand image, presentation, functionality, system performance, interactive behavior, and assistive capabilities of a system, product or service (ISO, 2018). It also results from the user's internal and physical state resulting from prior experiences, attitudes, skills, abilities, personality and from the context of use (ISO, 2018).

A user using a car display will not only experience the interaction with that display but also the underlying information and their attitude towards the car company will also affect the UX (Boström & Ramström, 2014). Thereby, when designing for user experience in vehicles, one need to take into account is how to get the users' acceptance to the information system (Boström & Ramström, 2014).

2.6. Vehicle/ environment-based factors influencing performance in the transition

There is a range of factors contributing to the performance in the automation, not only focused in the driver, but in the vehicle/environment conditions too. We will describe in this topic in more detail these factors, that are: time budget, human machine interface and road/traffic scenario.

2.6.1. Time budget

The time to the drivers resume the control is the primary area of interest in the study of transitions in highway autonomous driving nowadays (e.g. Gold et al., 2013). Damböck, Farid, Tönert and Bengler (2012) performed a study where compared different time budget to drivers following a take-over request. They compare time budgets of 4s, 5s, 6s, and 8s, the authors found that, compared to when in manual control, drivers crashed significantly more frequently in all time budget conditions except for the 8s condition. Gold et al. (2013) tested driver behavior following an auditory take-over request at either 5s or 7s time-to-collisions, with a stationary vehicle in the lane ahead. Participants given 5s time budget react faster in all considered variables compared to drivers given a longer time budget (7 s), but they tended to have fewer glances at the rear and side mirrors before a lane change and were also less likely to use an indicator. The authors conclude that the drivers who were given a 5s time budget showed worst behavior following a take-over comparatively with a time budget of 7s.

Studies of take control with small time budget (<6s) to simulate a critical situation (eg: van den Beukel and van der Voort, 2013; Zeeb, Buchner and Schrauf, 2015) showed that the drivers were unable to avoid colliding with a braking lead vehicle. We can conclude with these studies that is necessary the automated systems give time to the driver resume the control with a good SA.

According Louw and colleagues (2017) is important define operational and technical parameters for the design of automated driving systems, focusing on driver responses given different time budgets arises.

2.6.2. Human-Machine Interface (HMI)

The Human-Machine Interface is used to provide system feedback to users, which has an important role in driving, to create appropriate human-automation interactions (Norman, 1989). When the feedback is incorrect or insufficient could result in drivers developing inaccurate mental models, which could lead to errors in decision or action, and in consequence to accidents (Sarter & Woods, 1991). Norman (1989) proposed a definition of four design criteria for human machine interface in automation, as follows: *"Appropriate design should (1) assume the existence of error, (2) it should continually provide feedback, (3) it should continually interact with operators in an effective manner, and (4) it should allow for the worst of situations"*.

In autonomous vehicles, the design of feedback and warning systems usually communicate information in range of modalities (for a review, see Manca, de Winter and Happee, 2015), various meanings (Beller, Heesen, & Vollrath, 2013; Lorenz et al., 2014), and sequences (Radlmayr, Gold, Lorenz, Farid, & Bengler, 2014).

The human-machine interaction, or so called human-computer interaction has been shown to have some mediating effect on performance in the transition. Concerning modality, Naujoks, Mai, and Neukum (2014) assessed driver performance following ’visual’ and ’visual + auditory’ during take-over requests in three different traffic scenarios. They found that the reaction time of hands on steering wheel and maximum lateral position were significantly worst for the ’visual’ group compared to the ’visual + auditory’ group, as well as the difficulty of scenario increase, the differences between modalities increase too. Lee et al. (2002) found that an auditory warning provoked significantly shorter braking times, irrespective of whether participants were distracted or not.

Lorenz et al. (2014) investigated two augmented reality concepts for warnings and information during the transition. An "AR green" concept displayed a safe corridor showing the driver where they can steer through, an "AR red" concept projected a restricted corridor directly onto the road scene, showing the driver where they must not steer through, while, and a control condition provided no AR information. In terms of take-over time the results showed no difference between the two concepts, however, drivers in the "AR green" concept had better vehicle control, obtained through steering trajectories, and longitudinal and lateral accelerations.

In a driving simulator study, Beller et al. (2013) used symbols of automation uncertainty in an attempt to improve driver-automation interaction. They compared the use of automation “uncertainty” against “no uncertainty” information, in conditions of “high automation reliability” and “low automation reliability”. The authors founded positive values to displaying automation “uncertainty”, once that increased time-to-collision in the case of automation failure. It’s very important a good feedback of displays in the new automated systems.

We can conclude that the that the human-machine interface plays an important role in the drivers’ SA, once that help the drivers to perceive and understand the surroundings and vehicle state, as well as the display in seen as an essential part to the drivers in the different levels of autonomous driving (Wang & Söffker, 2016).

2.6.3. Road and traffic scenario

Automated driving system have been studied in different road conditions during the transitions and typically try simulate the actual or predicted limitations or boundaries system (Louw, 2017). These different road conditions include situations where the car is reaching a surrounding vehicle, a road works/accident and technical failure (Louw, 2017).

Radlmayr, Gold, Lorenz, Farid and Bengler (2014) investigated the effect of varying non-driving related tasks and traffic situations on the quality and process during a take-over. The experiment was conducted in a high-fidelity simulator and used the standardized visual Surrogate Reference Task (SuRt)[14] and the cognitive n-back task[15] to simulate the non-driving related tasks. The study included four traffic situations each with a time budget of 7s and three lanes: In situation 1, all the lanes were blocked to the driver follow when the driver receive the takeover request, in situation 2, only the right lane was blocked with an obstacle, in situation 3, only the left lane was blocked with an obstacle and in situation 4 the obstacle was in the middle lane. They conclude that traffic density and traffic scenario had a substantial effect on take-over quality in a highway. In a

[14] Secondary task created by ISO14198 (2012) to get the driver out of loop. This task required participants to scan stimulus displays for the one stimulus that differed from others surrounding it.
[15] Secondary task where is presented a sequence of stimuli one-by-one. For each stimulus, they have 3 possible correspondences in a keyboard.

similarly study, Kircher, Larsson and Hultgren (2014) found that the type of scenario and if the driver was pre-warned decrease the response time. The situational awareness and process of resume control is equally influenced by traffic density (Gold, Körber, Lechner, & Bengler, 2016; Jamson, Merat, Carsten, & Lai, 2013). Naujoks and coleagues (2014) founded the opposite, that the traffic scenario doesn't influence the takeover. There isn't a consensus about the traffic conditions, however most of the studies presented show that the traffic conditions influence the transitions.

2.7. Displays

Displays are a means of supporting tasks that require divided attention without compromising attention required for the primary task (Wickens, Christopher D., Hollands, Justin G., Parasuraman, 2013). The main objective of the displays is aim to improve driver safety, efficiency, performance, and comfort through the support of information and communication technology (Pauzie, 2015).

Displays are seen as a help to the driver increase his/her situational awareness (McDonald, 2016) and it is seeing like a help to reduce the number of traffic accidents related to change or inattentional blindness (Wickens, Christopher D., Hollands, Justin G., Parasuraman, 2013). Pauzie (2015) pointed that the visual channel is the most important during driving, with 90% of all the information being perceived by this channel.

We will describe in this topic in more detail these displays, that are: Instrument cluster, heads up display, augmented reality screen and central console. These displays will be subject to manipulation in this study, making part of our independent variables.

2.7.1. Instrument cluster

Different names have been associated with “instrument cluster” (IC) as “Driver information Module” (DIM; eg: Boström & Ramström, 2014) or “Heads Down Display” (HDD; eg: Liu & Wen, 2004) . This display is the main area in modern cars for displaying driving related information. This display is a part of the car’s dashboard and it’s located behind the steering wheel in front of the driver. This location is to provide easy access to information through short glances (Boström & Ramström, 2014).

By law, some information displayed in the IC is mandatory, such as speedometer, fuel and turn signals (Olaverri-Monreal, Lehsing, Trubswetter, Schepp, & Bengler, 2013). Traditionally the IC has been mainly analog with several gauges, two larger for displaying speed and revolutions per minute but it also contains smaller gauges for fuel and heat and an area for warning messages (Boström & Ramström, 2014). With technological advances, digital displays have replaced the analog gauges (Howard, 2012). With digital displays replacing the physical gauges, different ways of displaying information have been introduced, mainly the possibility to have dynamic information in this display (Boström & Ramström, 2014). In order to read this display, while driving, drivers must take their eyes off the road ahead, being this unavoidable and would seem to affect driving safety (Liu & Wen, 2004). Zwahlen, Adams and DeBals (1988) pointed out that if a driver’s gaze leaves the road for longer than 2 s, then traffic accident risk is significantly increased.

2.7.2. Heads Up display (HUDs)

The head-up display (HUD) is a display projected on the windscreen or on a transparent screen in front of the driver and gives a feeling of a secondary layer on top of reality (Boström & Ramström, 2014). In comparison to the instrument cluster display, the HUD decrease the duration and number of the driver’s sight deviations from the road (Liu & Wen, 2004), once that present the visual information within the driver's forward field of view, at a focal plane further into the forward scene (Park & Park, 2019). Park and Park (2019) assume that the automotive HUDs have the potential to improve driving performance and safety, once that the driver has advantages in information access costs. Some studies have empirically demonstrated the positive effects of HUDs comparatively to the instrument cluster in terms of performance of primary and secondary driving tasks (Liu & Wen, 2004; Wittmann et al., 2006), driver distraction and workload (Weinberg, Medenica, & Harsham, 2011).

One of the main benefits expected from HUD's is a decrease in the accommodative shift and reduced re-accommodation demands for drivers to fixate upon external targets (Pauzie, 2015). Elderly people are expected to be the main beneficiaries of the shorter focal transition, given their restricted accommodative range (Kim & Dey, 2009) and because it’s no longer having to look through the near correction (lower part) in their eyeglasses as required to get information in the instrument cluster (Gish & Staplin, 1995).

HUD reduces focal accommodation time (Merenda, Smith, Gabbard, Burnett, & Large, 2016), and also allows improving “eyes on the road” time by reducing the number of glances to the instrument cluster (Horrey, Wickens, & Consalus, 2006).

Liu (2003) pointed that the HUD allows more time to scan the traffic scene, quicker reaction times to external road events, less mental stress for drivers, earlier detection of road obstacles, and easier learning phase to use. Ando, Okabayashi, Okumura, and Nagahara (2010) concluded in their study that the recognition error rates is lower. In bad weather conditions, HUD improve the understanding of the vehicle’s surrounding (Charissis & Papanastasiou, 2008).

Land and Horwood (1998) restricted the vision of drivers to determine what visual information is necessary to control a vehicle. They found that drivers use information 4°

degrees below the horizon to guide steering and information 7.5° below the horizon to maintain position within a lane. The combination of this information allows drivers to accurately use visual information for vehicle control, especially at high speeds (Land & Horwood, 1998). Most of the early HUDs, the standard focus distance was 2.0 m (Gabbard, Fitch, & Kim, 2014). Similarly, the automotive community generally recommends a focus distance to the HUD between 2.0 and 2.5 m. This may be close to the driver's resting focus (2–3 m) and is based on empirical studies about the effect of image distance on the extraction of information from the display (Gabbard et al., 2014).

Potential drawbacks of HUDs must also be considered in these kinds of displays. The recorded scan saving time may be valid only for low workload situation and may not generalize to higher-workload conditions (Gish & Staplin, 1995). The interference of contrast may mask external targets and superimposing symbology on the forward driving scene (Pauzie, 2015).

There is empirical evidence that the lens accommodation (i.e., optical focus of the eyes) is not at infinity when viewing the heads up display, but somewhat nearer (Iavecchia, Iavecchia, & Illiana, 1988). One of the main problems with HUDs is that the objects on road are perceived smaller or more distant than in the reality, cause by the amount of this deviation, or misaccommodation (Smith, Meehan, & Day, 1992).

Tufano (1997) argued that the focal distance of the drivers using HUD may affect visual attention and clutter or block drivers' view and by consequence cause serious safety hazards. Tretten, Gärling, Nilsson and Larsson (2011) founded in their study that most of the drivers did not want the HUD image within their focal area while driving. They found that the drivers prefer to see the image below, right or to the left of the immediate area tested. The effectiveness for safety critical situations remain to be determined, once that there is an apparent tradeoff in HUD images, by a side this display increased eyes-on-the-road time and by other side increased visual clutter from HUD symbology (Gish & Staplin, 1995).

Other of the main problems using HUD is the cognitive capture, that happen when there is a special difficult of the driver to get information in the display, as read a text, so the driver may stay more focus in the display than on the road (Pauzie, 2015). This cognitive capture occurs all the times that the driver is distracted because the presence of numerous visual stimuli (Pauzie, 2015). In summary, occurs cognitive capture when the driver attention resources are bigger to the HUD than to the road, and by consequence can affect the drivers' performance and safety (Pauzie, 2015).

2.7.3. Augmented reality

Augmented Reality (AR) is seen by car manufactures as the next-generation visualization technology for in-car driving displays (Kim & Dey, 2009). AR uses simulated graphics or images in the windshield, superimposed over real world objects or environments (Wickens, Christopher, Hollands, Justin, Parasuraman, 2013). The information in augmented reality screen appears where the driver is looking on. While the information in HUD is in 2D, the augmented reality use information in 3D, adapting to the environment conditions. This display allow display an obstacle in their real position, reducing the number of glances to get critical visual information relevant for the driver (Pauzie, 2015). According Gabbard and coleagues (2014), the most obvious benefit of AR is the ability for information to be presented and perceived without forcing drivers to look down. AR require less mental load for interpretation, once that the information appears close to the environment where the driver' attention resources is (Pauzie, 2015). Spatial information in the environment can be transferred from the current displays (IC or HUD) to AR screen (Pauzie, 2015). As all the technologies, AR is seen like a new opportunity for fast and efficient information, however also generate new problems (Pauzie, 2015). Technically, many challenges are associated with this display, such as weather conditions, illuminations and geometric distortions (Dogan et al., 2017).

Lee and See (2004) argued that the trust and reliance can increase according with the increasing of realism. AR display may lead to an advantage comparatively to the other displays, once that the driver can perceive the objects in their real surroundings (Ng-Thow-Hing et al., 2013). AR display presents some potential drawback comparatively to the HUD, as well as phenomena of perception tunneling and cognitive capture (Pauzie, 2015). Tönnis, Lange and Klinker (2007) argued that AR decrease the lane deviation comparatively to other displays, once that displaying the drive path in the windshield. Pauzie (2015) mentioned that AR may improve driver' visualization at night, the obstacles warning perception and enabling effective and efficient information transfer directly understandable by the driver.

AR decrease the visual distraction, divided attention and cognitive load, once that the information appears directly in the driver attention resources, decrease the driver's sight deviations, making easier for the driver translate the virtual information (Pauzie, 2015)

Kim and Dey (2009) showed that elderly drivers liked the fact that the AR allowed them to look at both the navigation display and the street at the same time and mentioned that this made it easier to notice pedestrians crossing the street. In this way, elderly drivers, specially, showed beneficiate from AR comparatively to other displays because decrease the impact of divided attention and cognitive load, that in this population is already smaller. Gabbard and colleagues (2014) argued that the drivers do not have to shift attention away from the driving scene, gaze is not distracted, and drivers do not need to change focus and accommodation as much when compared to traditional automotive display because the information is presented in the driver's direct line of sight, and is overlaid on the objects it is referring to.

Some open questions remain about AR, as the optimal design to support driver performance (Gabbard et al., 2014), the effects in performance, safety and mental workload (Pauzie, 2015).

In summary, AR is seen as a new opportunity to the car manufactures, however difficult technical, usability, and cost issues related have difficult the implementation of this display (Gabbard et al., 2014).

2.7.4. Central Console

The "central console" (CC) or so called "center stack display" (CSD) (eg: Tretten, 2008) is the display placed in the center of the instrument panel between the driver and the passenger seat. The central console normally has non-driving related information and controls (Boström & Ramström, 2014). Usually, in this display, the car show climate, media system, car phone and mobile phone integration, navigation system, radio, TV, web browser, online music, internet sharing and individual applications (Boström & Ramström, 2014). The input part of the central console has usually consisted of physical controls (buttons) and with haptic feedback (Boström & Ramström, 2014). Like in instrument cluster, the central console has been replaced partially the analogic by a digital display due the technological advances. This new digital displays are controlled either with separate physical controls (button) or with a touch interface (Boström & Ramström, 2014). With the central console, many new possibilities have been introduced and with dynamic information more features can be added (Boström & Ramström, 2014). Reversing camera and night vision are some news systems are being developed in this display. With each new generation has the screen been made bigger, eg: Tesla Model 3, that use a big central console, it is not unlikely that it will replace all the previous controls in the central console as seen in many concepts and even some production cars.

3. Objectives

In this topic, we explain in detail the objectives of this study.

The main objective of the study is to compare two concepts of displays (Augmented Reality and Instrument Cluster) concerning driver performance, safety driving, both in manual and autonomous driving. Several criteria variables to compare the two displays was chosen according internal orientations of CTAG and the previous literature revision, and are:

- Preference;
- Trust;
- Situational awareness (SA);
- Acceptance (Usefulness and Satisfaction);
- Timing aspects (Reaction times of hands on during Give back, reaction time of take over during GB and reaction time during rear end collision);
- Quality aspects of driver behavior (behavior of hands and foot during give back and rear end collision and gaze direction during rear end collision).

We made this comparison in specific moments of driving, that were:

- Manual mode;
- Rear end collision → manual mode;
- Availability of autonomous driving function;
- Activation of autonomous driving function → transition manual to autonomous;
- Give back → transition autonomous to manual;
- Deactivation of autonomous driving function → manual mode.

The comparisons between the two interfaces were performed for the following specific objectives:

Specific objective 1 - Compare confidence and preference of driver using Augmented Reality (AR) screen and Instrument Cluster (IC) during manual mode.

Specific objective 2 – Compare Operational Area in AR and IC during availability moment, concerning preference, situation awareness, usefulness and driver satisfaction.

Specific objective 3 - Compare AR screen and IC during Activation concerning preference, situation awareness, usefulness, driver satisfaction and confidence.

Specific objective 4 - Compare AR concept and IC concept during Give Back (Visual-auditory warning) when there is secondary task (watch a movie) in Central Console and when there isn't secondary task concerning preference, situation awareness, usefulness, driver satisfaction, driver behaviors and reaction times.

Specific Objective 5 - Compare Operational area and IC during AD deactivated (Autonomous driving deactivated) concerning preference and situation awareness.

Specific Objective 6 - Compare AR area and IC during warning to rear end collision (obstacle) concerning type of reaction, reaction times, and driver's security lane change.

4. Method

We have structured this method in the following way; first we present the main organization of the study in driving simulator. There, the way how the drivers could activate and deactivate the autonomous driving function is explained. We then explain in detail the autonomous driving function used, where the different transitions between levels of autonomous driving tested and who and how can perform it, are also explained. We then clarify the concepts of the displays used, as introduction to the human machine interface tested (displays). Then we describe the visual part of the displays that we compare in simulator ("AR concept" and "IC concept") and their specifications. We then go to the explanation on the experimental design. After that, we describe the process of data collection, the technical description of the displays tested and the driving simulator used. Then we describe the sample of this study. Finally, we describe the material used during the user tests, the procedure and the scenario.

4.1. Main Organization of the Study

This study had two stages of development: the learning phase and the test phase, which are following presented.

4.1.1. Learning phase

This phase had a duration of 6 minutes and started on manual driving, for adapting to the vehicle, to the track and to the activation process. They also drove in autonomous mode, to understood how the system and the commands worked, disabling the autonomous function. During the learning phase, there were two Give Back (GB). This topic is explained in more detail in 4.10.1.

4.1.2. Test phase

The participant drove on both ways: manual and autonomous way, being the moments on manual mode shorted than autonomous. In total, there were four give back (transition from autonomous to manual mode), all because the normal end Traffic Jam (TJ)[16]. Also, there were six moments for the secondary tasks (ST) in manual mode and two in autonomous mode, two for interviews and some moments for verbalizations and observations. This topic is explained in more detail in chapter 4.10.1.

[16] End of Traffic Jam means that terminate the traffic that allowed activate the function and the car will ask the driver control again, when the speed of autonomous vehicle exceed the 60km/h.

4.1.2.1. Activation Process

When the vehicle detects a Traffic Jam (TJ) situation, the system sends the information, throughout the human machine interface (display) and sound, that the autonomous function is available;

The driver activates the function using the autonomous driving button. This button is located on the left side of the car, close to the steering wheel;

Then, the system informs the driver that the autonomous function is activated throughout the human machine interface (display) and sound.

4.1.2.2. Deactivation Process

The autonomous system can request the manual control of the vehicle due to three situations: Close Road/obstacle, Failure and End of Traffic Jam. This study focuses only on the third situation (End of Traffic Jam). To deactivate the autonomous driving, the driver must:

When receive the Give Back message in the display, put both hands on the steering wheel and the foot on the pedal (accelerator or break);

Also, the driver can request to the system the control of the vehicle, throughout an override (1) or a Take back (2):

(1) Making a movement on the steering wheel with a torque of 2,7 N minimum.

(2) Also with the both hands on the steering wheel and the foot on pedal during 6 seconds without the car ask the control.

4.2. Autonomous function used

In this thesis, the transition was defined as, the change of function state, where we include:

- Manual mode (Level 0 SAE) – Normal driving without help as we are get used in our cars.
- AD available (Level 0 SAE) – The same functional state than before, however the car informs the driver that Autonomous Driving (AD) is available.
- AD activation (Level 3 SAE) – After the driver press AD button (when the function is available) start this state, where there is an advice during 3 seconds saying, “AD

activated”, and in this moment AD is already activated. After 3 seconds, we pass to the next state, AD activated.

- AD activated (Level 3 SAE) – This state starts 3 seconds after AD activated and the difference to the moment before is that disappears the message, all the other HMI keep with the same graphic design.
- Give Back (Level 3 SAE) – In this state, the car asks the control to the driver. This state can start because one of these 3 reasons (End of traffic, system failure or obstacle detection). This state has a duration of 10 seconds. To deactivate this state, the car needs the driver action (Hands on SW + Foot on pedal). If the driver doesn't do nothing during this state, the car stops (Speed = 0 km/h).
- Give me Back (Level 3 SAE) – In this state, the driver asks the control to the car when the function is activated. After the driver activate this state, pass directly to “Give Back” state.
- AD deactivated (Level 0 SAE) – This state is after a give back, it's the first 3 seconds in manual mode after the car be in autonomous mode.
- The transition Manual Mode to AD available it's always initiated by automation to driver, and happen when:

  - Current speed it's above 60 km/h + Traffic situation.
- The transition AD available to AD activation it's always initiated by driver, when:

  - Driver press AD button.
- The transition AD activation to AD activated it's always initiated by automation, when:

  - The time of autonomous driving it's >= 3 seconds.
- The transition AD activated to Give Back can to be initiated by driver or automation.

  It's initiated by driver when:

  - Pulse brake >= 5 seconds;

  - Put hands on Steering wheel (SW) >= 5 seconds;

  - Hands action >= 5 seconds;

It’s initiated by automation when:

- End of TJ (speed >= 60 km/h);

- System failure;

- Appears an obstacle.

- The transition AD activated to Give Me Back (GMB) it’s always initiated by driver, and happens when the driver:

  - Press brake pedal + press AD button;

  - Press AD button;

  - Press gas pedal + press AD button;

- The transition AD activated to AD deactivated it’s always initiated by driver in level 3 SAE, and happen when:

  - Hands on >= 3 seconds + press AD button;

  - Press gas pedal >= Speed system + Hands action;

  - Press gas pedal >= 5 seconds;

  - Press gas pedal < speed system + hands action;

  - Press gas pedal < speed system + hands on >= 5 seconds;

  - Hands on < 3 seconds + press AD button;

  - Press brake pedal + hands on;

  - Hands action + press AD button.

- The transition Give back to AD deactivated can to be initiated by driver or automation.

  It’s initiated by driver when:

  - Press AD button + Hands on;

  - Press gas pedal >= speed system + Hands on;

  - Press gas pedal < speed system + Hands on;

  - Press brake pedal + Hands on.

It's initiated by automation when:

- During 10 seconds of GB the driver don't put the hands-on SW. The car makes an emergency stop.

- The transition GMB to AD deactivated it's always initiated by driver in level 3 SAE, and happen when:

  - During the first 3 seconds of Give me back the driver put the hands on Steering Wheel;

- The transition GMB to AD activated it's always initiated by automation in level 3 SAE, and happen when:

  - During the first 3 seconds of Give me back the driver doesn't put the hands on Steering Wheel;

- The transition AD deactivated to Manual mode it's always initiated by automation, when:

  - The time of manual mode after the automation it's >= 3 seconds.

4.3. Concepts

In this topic, we describe the concepts used to the displays tested.

The Figure 2 show us the part of windshield used to project the augmented reality screen[17]. This screen is divided in Augmented reality area (up part of augmented reality screen) and in Operational area (HUD; Bottom part of augmented reality screen). The information displayed in AR area adapt to the real information in real time, where the lines that appears in this screen augmented the real lines of the road. By other side, the information displayed in operational area appears projected over the road. The Instrument cluster[18] is the screen behind the steering wheel and the central console[19] is in the cockpit, between the driver and the passenger (Figure 3).

[17] Explained in more detail in topic 2.7.3
[18] Explained in more detail in topic 2.7.1
[19] Explained in more detail in topic 2.7.4

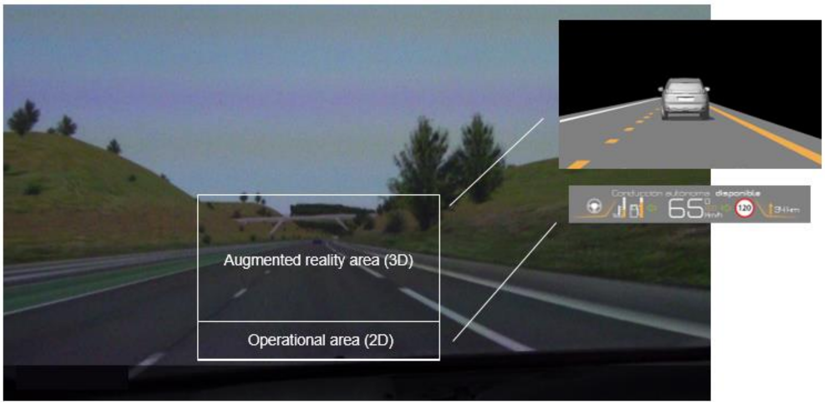


Figure 2 – Windshield where is possible see the Augmented Reality screen divided in Augmented reality area and Operational area.

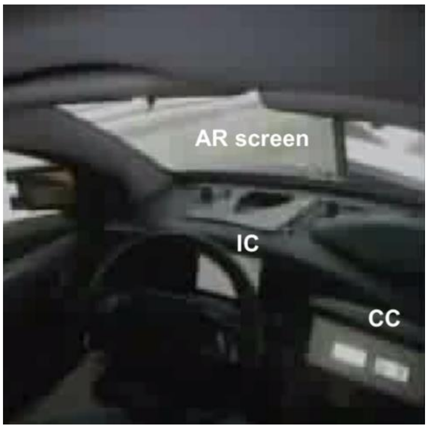


Figure 3 – Displays tested in this study.

4.4. Human Machine Interface

In this topic, we will explain the human machine interface (HMI) that we evaluated in this study. We will explain the differences between concepts that we tested in different moments. The logic (color and content of information) of the autonomous driving button and the information in central console was the same for both concepts during all the test. We did this to these variables to the participants focus in the displays that were being evaluated in this study (instrument cluster and windshield). The difference between concepts were the place where was showed the information. The "AR concept" used the windscreen to show all the car information (adaptation of design PSA group, innovation committee (2015) - Figure 4) and the autonomous function, by other hand, the "IC concept" used the IC to show the car info and autonomous function, and the operational area (bottom part of windscreen or as appears in literature: Heads Up Display) to show specific information about car info (current speed and speed limit). The "IC concept" tried simulated the information that is currently displayed by the brands. The design that we evaluated in both concepts of this study were validated by users in previous studies in CTAG.

Figure 4 – Reference used to this study. PSA group, innovation committee (2015). (Source: https://www.youtube.com/watch?v=0OdZXf1E7Z8)

4.4.1. Manual mode

In both concepts during manual mode were showed the same information in main displays (windscreen or instrument cluster) (Figure 5):

- Bars fuel level (%);
- Bars car temperature (ºC);
- Fuel icon;
- Temperature icon;
- Current speed (km/h);
- Speed limit (km/h);
- Letter of gear change;
- Lines in orange color;

Both concepts had the button without color and the Central Console (CC) in gray color with two options to select, ADAS or Video.

Setting 1 “AR concept” showed all the information about this moment in operational area, except the line marks (central and lateral right) in orange color that only appeared in augmented reality area (Figure 5, left).

Setting 2 “IC concept” showed the same information that setting 1, but in instrument cluster. This concept has duplicate the current speed and speed limit in operational area/ heads up display (HUD). (Figure 5, right).

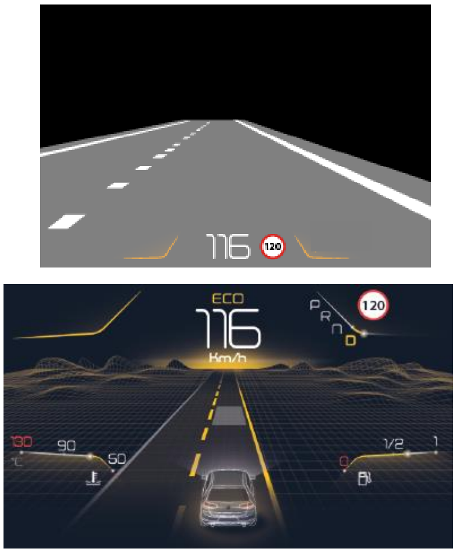
Augmented reality concept	Instrument Cluster concept
	

Figure 5 – HMI during manual mode. Left – AR concept, right – IC concept.

4.4.2. Availability

In this moment, both concepts showed the same information present in topic 4.4.1 Manual mode, where it was added the AD icon and the text ‘autonomous driving available’.

Both concepts had a little sound when the AD stayed available, as a “beep”.

Setting 1 “AR concept” show all the information about this moment in operational area, where we can highlight the AD icon on the left side and the text about this moment over the car information (Figure 6, left).

Setting 2 “IC concept” show the same information that setting 1, but in instrument cluster, the AD icon appeared on the left side of IC and the text about this moment appeared under the current speed in IC too (Figure 6, right).

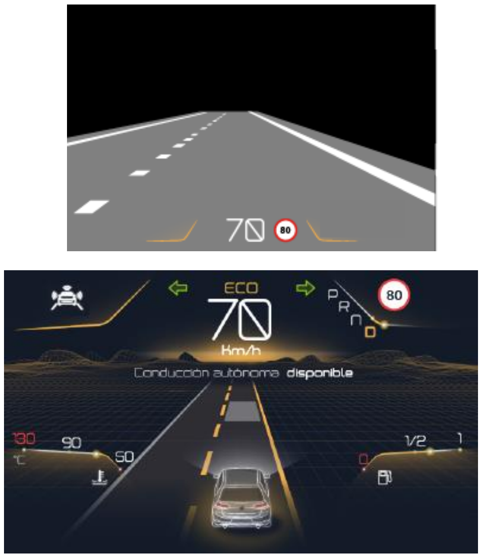
<table>
<tr><th>Augmented reality concept</th><th>Instrument Cluster concept</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Figure 6 – HMI during the first 3 seconds of TJC available. Left – AR concept, right – IC concept.

After 3 seconds of AD available, if the participant didn't press the AD button, the interface had a little modification in both concepts.

Setting 1 "AR concept" after 3 seconds disappeared the text of the operational area, only keep about this moment the AD icon in white color (Figure 7, left).

Setting 2 "IC concept" after 3 seconds disappeared the text of the IC, only keep about this moment the AD icon in white color (Figure 7, right).

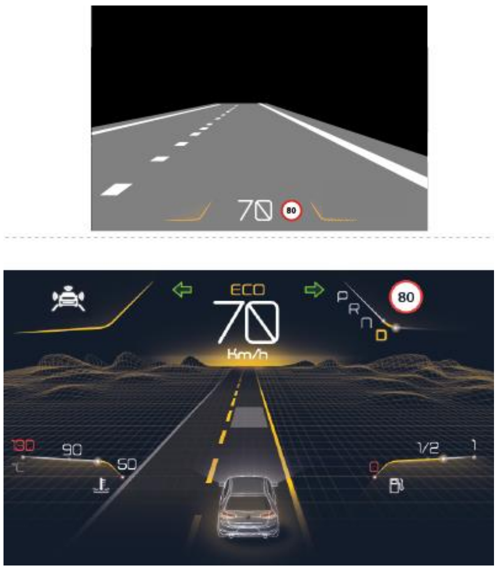
<table>
<tr><th>Augmented reality concept</th><th>Instrument Cluster concept</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Figure 7 - HMI after 3 seconds of AD available. Left – AR concept, right – IC concept.

4.4.3. Activation

In both concepts during autonomous mode were showed the same information in main displays (windscreen or instrument cluster) (Table 1):

- AD icon;
- Fuel icon;
- Maximum fuel (km);
- Current speed (km/h);
- Speed limit (km/h);
- Lines in blue color;
- Time gap in blue color.

Lane keeping can be especially critical for inexperienced drivers and lane-keeping support can be very desirable for bad weather conditions and darkness (Pauzie, 2015).

Both concepts had a little sound when the AD stayed activated, a "beep", as during the availability moment.

Both concepts had the AD button without color and the CC in gray color with two options to select, ADAS or Video like in Manual Mode. There was no difference in color and information in central console between modes for minimize confusing effects in the results.

The difference between availability moment and activation moment was (Table 1):

Disappeared:

- Bars fuel level;
- Temperature icon;
- Bars car temperature (^{o}C);
- Letter of gear change.

Maintain but changed of color:

- Lines over the road lines (orange to blue);
- Current speed (km/h) (White to blue);
- Design color (orange to blue);
- AD icon (White to blue).

Appeared new:

- Autonomy fuel (km);
- Car mark;
- Text message “Autonomous driving activated”.

Table 1 – Summary of the displayed information during the different moments in both concepts.

	Manual mode	Availability first 3 sec	Availability after 3 sec	Activation	Activated (after 3 seconds)	Give Back	TJC deactivated
Fuel icon	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bars fuel level (%)	Yes	Yes	Yes	-	-	-	Yes
Autonomy fuel (km)	-	-	-	Yes	Yes	Yes	-
Temperature icon	Yes	Yes	Yes	-	-	-	Yes
Bars car temperature (ºC)	Yes	Yes	Yes	-	-	-	Yes
Letter of gear change	Yes	Yes	Yes	-	-	-	Yes
Lines over the road lines[20]	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Current speed (km/h)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Speed limit (km/h)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Car mark[21]	-	-	-	Yes	Yes	Yes	-
Design color	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Text message	-	Yes “Autonomous driving available”	-	Yes “Autonomous driving activated”	-	Yes “Take control”	Yes “Autonomous driving deactivated”
AD icon	-	Yes	Yes	Yes	Yes	Yes	-
Pedals icon	-	-	-	-	-	Yes	-
Steering wheel icon	-	-	-	-	-	Yes	-

[20] Information that in “AR concept” appears in augmented reality area.
[21] Information that in “AR concept” appears in augmented reality area

Setting 1 “AR concept” showed all the information about this moment in windscreen (Figure 8, left). The car mark and the lines over the road lines in blue appeared in augmented reality area and all the other information appeared in operational area.

Setting 2 “IC concept” showed the same information that setting 1, but in IC. This concept had duplicate the current speed and speed limit in operational area/ heads up display (HUD). (Figure 8, right).

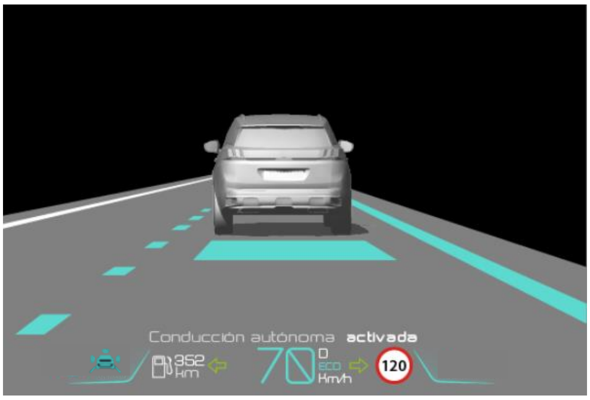
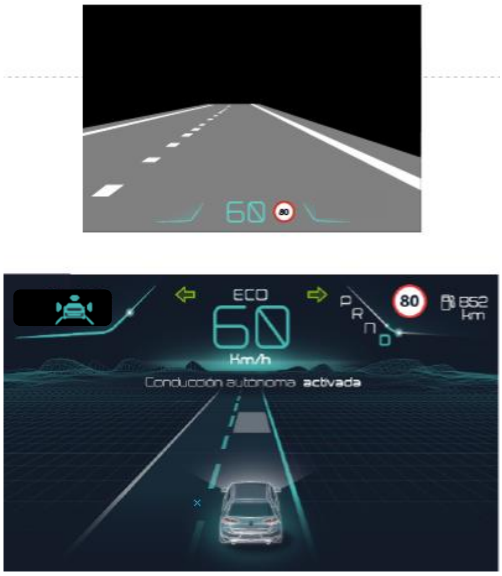
Augmented reality concept	Instrument Cluster concept
	

Figure 8 - HMI during the first 3 seconds of AD activation. Left – AR concept, right – IC concept

4.4.4. Activated

After 3 seconds of AD activated, disappeared the text in both concepts.

Setting 1 “AR concept” after 3 seconds disappeared the text of the operational area, all the other information that appeared was the same than in activation moment setting 1 (Figure 9, left).

Setting 2 “IC concept” after 3 seconds disappeared the text of the instrument cluster, all the other information that appeared was the same than in activation moment in setting 2 (Figure 9, right).

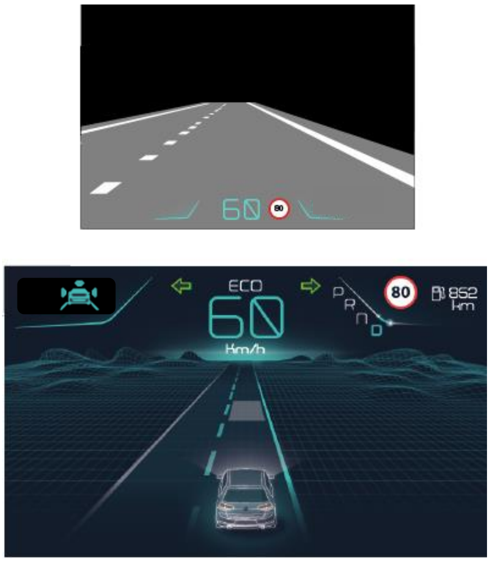
Augmented reality concept	Instrument Cluster concept
	

Figure 9 - HMI after 3 seconds of AD activated. Left – AR concept, right – IC concept.

4.4.5. Give back

In both concepts during Give Back were showed the same information in main displays (windscreen or instrument cluster) (Table 1):

- Fuel icon
- Autonomy fuel (km)
- Lines over the road lines
- Current speed (km/h)
- Speed limit (km/h)
- Car mark
- Design color
- Text message
- AD icon
- Pedals icon
- Steering wheel icon

Both concepts had a sound during the give back, a message ‘take control’ following by different sounds as “bips”. This sound only appeared during give back moment.

Both concepts had the button without color and the CC in gray color with two options to select, ADAS or Video, as during the other moments.

The difference between AD activated ant give back moment was (Table 1):

Disappeared:

- Lines over the road lines
- Car mark

Maintain but changed of color:

- Design color (blue to red)

Appeared new:

- Text message “Take control”
- Pedals icon
- Steering wheel icon

Setting 1 “AR concept” showed all the information about this moment in windscreen (Figure 10, left). The text message “Take control, the pedals icon and the steering wheel icon appeared in augmented reality area. The information in operational area during this moment it’s the same that when was AD activated.

Setting 2 “IC concept” showed the same information that setting 1, but in IC. This concept had duplicate the current speed and speed limit in operational area/ heads up display (HUD). (Figure 10, right).

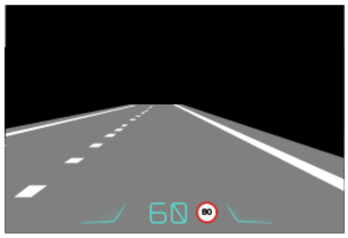
Augmented reality concept	Instrument Cluster concept
	

Figure 10 – HMI during Give Back. Left – AR concept, right – IC concept.

4.4.6. Deactivation

In this moment, both concepts showed the same information present in topic 4.4.1 Manual mode, where it was added the text 'autonomous driving deactivated'.

Both concepts had a little sound when the AD deactivated, a "beep" as when the function it's available and AD was activated.

Setting 1 "AR concept" showed all the information about this moment in operational area, where we can highlight the text about this moment over the car information. The lines that appeared in AR area changed the color to yellow again and disappeared the car mark (Figure 11, left).

Setting 2 "IC concept" showed the same information that setting 1, but in IC, the text about this moment appeared under the current speed (Figure 11, right).

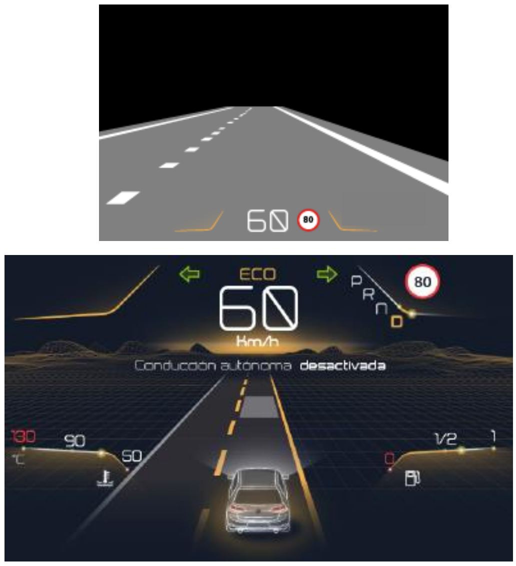
Augmented reality concept	Instrument Cluster concept
	

Figure 11 - HMI during first 3 seconds of AD deactivated. Left – AR concept, right – IC concept

4.4.7. Rear end collision

This moment happened during manual mode, the difference here was that some settings had forward collision warning (FCW) and other settings no, where maintain the same vision as present in 4.4.1 Manual mode.

Hayward (1972) defined time to collision (TTC) as “*the time required for two vehicles to collide if they continue at their present speed and on the same path*”.

Setting 1 “AR concept” replicated a Tesla model 3 (year 2018) FCW HMI for imminent rear-end car-to-car collisions and included an audio-visual warning issued at TTC 7sec. We used as reference distance 233 meters at 120km/h (Lorenz et al., 2014).

The audio-visual warning HMI consisted of a flashing square shape in the windscreen (augmented reality area) over to the car ahead (obstacle) indicating the nature and position of the threat, displaying the borders of a square shape in red color and a warning sound simultaneously issued at 64 dBA and repeated for 7.0 s (Figure 12, left).

Setting 2 “IC concept” issued the same warning as Setting 1 at TTC 7.0 s in a second stage, but the FCW HMI was presented only in IC (Figure 12, right).

Setting 3 “Baseline AR concept” appeared the same information that explained in topic Manual mode for AR concept. The difference to setting 1 in Rear end collision was that in this use case the information about the obstacle didn’t appears (no FCW and no sound).

Setting 4 “Baseline IC concept” appeared the same information that explained in topic Manual mode for IC concept. The difference to setting 2 in Rear end collision was that in this use case the information about the obstacle didn’t appears (no FCW and no sound).

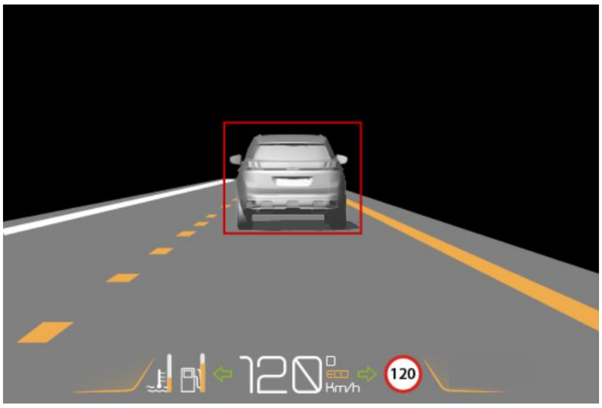
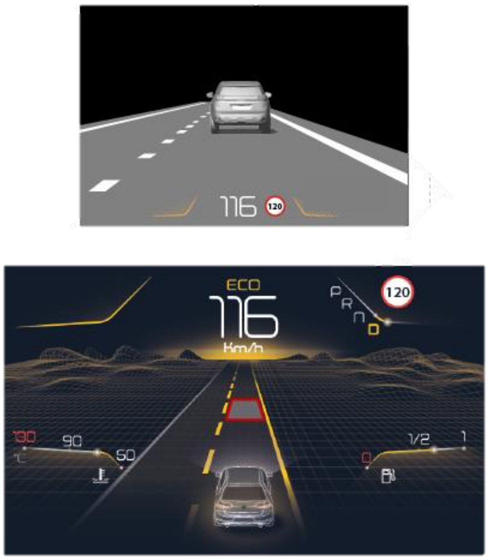
Augmented reality concept	Instrument Cluster concept
	

Figure 12 – HMI during rear-end collision event. Left – AR concept, right – IC concept

4.4.8. Secondary task

There were two secondary tasks during this test, one for manual mode and another for autonomous mode.

The secondary task during autonomous mode was watch a movie. The HMI showed the same information present in topic 4.4.4 AD activated, the difference was the HMI of central console, so Setting 1 and Setting 2 during this task had the same interface than topic 4.4.4 AD activated, except the interface of the central console respectively (Figure 13).

The secondary task during manual mode was just cognitive. The HMI showed the same information present in topic 4.4.1 Manual mode, so Setting 1 and Setting 2 during this task had the same interface than topic 4.4.1 Manual mode respectively.

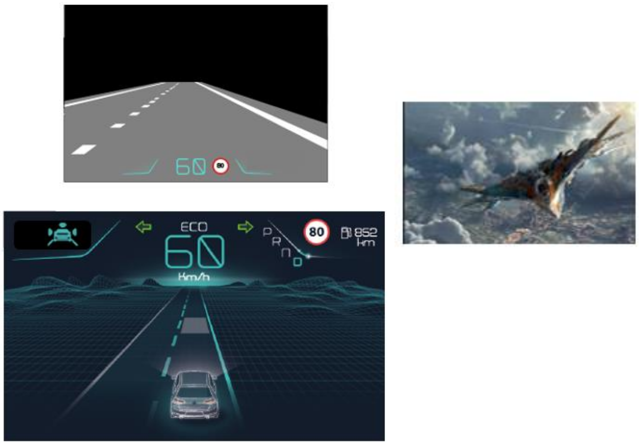
Augmented reality concept	Instrument Cluster concept
	

Figure 13 - HMI during secondary task in autonomous mode. Left – AR concept, right – IC concept

4.5. Experimental design

The study used a mixed design. The within subject had two factors. One, the HMI concept with two levels ("AR concept" and "IC concept")[22] and, Two, the secondary task with two levels (with and without secondary task). The between subject had one factor (type of warning used in a collision avoidance situation) with four levels ((1) Visual and auditory warning in augmented reality; (2) None warning in augmented reality condition (Baseline to AR concept); (3) Visual and auditory warning in instrument cluster; (4) None warning in instrument cluster condition (Baseline to IC concept)).

Thus, every participant experienced the two concept of HMI, "AR concept" and "IC concept" and the two levels of Secondary task. Every participant experienced only one of the four warning concepts representing the four possible combinations[23]: (1) Visual and auditory warning in augmented reality; (2) None warning in augmented reality condition; (3) Visual and auditory warning in instrument cluster; (4) None warning in instrument cluster condition. The participants were assigned randomly to the groups. The HMI that we used to AR concept was an adaptation of design PSA group, innovation committee (2015). The HMI that we used in IC concept was an adaptation of design from Peugeot 3008 SUV GT LINE (2017), where all the display it's digital. The design of function information was an adaptation of design from Cadillac CT6 (2018) and Audi A8 (2018)

[22] Explained in detail in topic 4.4
[23] Explained in detail in topic 4.4.7

explained in detail during topic 4.2. We create internally the icon to inform the drivers the function state. An icon that tried to represent a car connected to the environment. When didn't available, no icon appeared, when available, appeared the icon in white color, when activated we used the blue color and when the car asked the control we used the blue icon color. Our interface of IC concept did an adaptation of middle part of AUDI A8 design, in manual and autonomous mode, where we showed the ADAS 3D view. We used in both concepts a change of design color as main transition point, where we associate the yellow color to manual mode and the blue color to autonomous mode. The secondary task during autonomous mode was watch a movie, for the driver to be completely distracted. Zwahlen, Adams and DeBals (1988) pointed out that if a driver's gaze leaves the road for longer than 2 s, then traffic accident risk is significantly increased. This task tried to simulate a real secondary task during autonomous driving. The other secondary task was during manual mode, and that was a mental calculation task, (e.g. make successively backward counts of 3, starting with a high odd number in order to increase mental workload). This secondary task during manual mode had as objective to create driver engagement with the secondary task during manual mode. Thus, when in the last stage of the experiment, in manual mode, and the obstacle appears to the driver he/she was confident in the achievement of the secondary task. The "AR concept" with warning was visual and auditory. The visual warning was displayed in augmented reality area like Tesla Model 3 (2018), directly on the obstacle, with a rectangular 2D shape around the obstacle in red color[24]. Schall, Rusch, Vecera and Rizzo (2010) found that static cues for hazards had longer reaction times than using no cues, for that reason we used a dynamic warning around the obstacle. The auditory warning used was an adaptation of auditory warning FCW from Tesla Model S (2017), "bip bip bip". The AR concept without warning showed the same information as in manual mode to AR concept when appeared the obstacle, without visual neither auditory obstacle information. The IC concept with warning was also visual and auditory. The visual warning was displayed in instrument cluster, in ADAS 3D view, with a rectangular 2D shape around the obstacle ahead in red color. We used the same auditory warning used in "AR concept". The IC concept without warning showed the same information as in manual mode to IC concept when appeared the obstacle, without visual neither auditory obstacle information too.

[24] Possible see the design in topic 4.4.7

Concerning dependent variables, we analyzed gaze and driving data as well as subjective measures. During the give back moment, we evaluate timing and quality aspects (Gold et al., 2013; Kerschbaum, Lorenz, & Bengler, 2014; Lorenz et al., 2014). The timing aspects describes the time sequence of drivers´ actions after appears the message. We calculated gaze reaction, road fixation, hands on and take over time. The quality aspects evaluated were the types of reaction and trajectories. *Gaze reaction* was calculated as the time since appears the GB message until the first saccade from the central console (Lorenz et al., 2014). *Road fixation* was calculated as the time since appears the GB message until the first glance is at the scenery (Lorenz et al., 2014). *Hands on* was calculated as the time since appears the GB message until the driver has his or her hands on the steering wheel (Lorenz et al., 2014). *Take over time* was calculated as the time since appears the GB message until the driver put him/her hands on steering wheel and foot in brake or accelerator pedal. *Types of reaction* was categorized into two groups of interests: brake and steer or accelerator and steer (Gold et al., 2013). Trajectories were calculated since 5 seconds before the GB message until 5 seconds after participant take control.

With other entities in the simulation were recorded by our driving simulator software at a frequency of 10 Hz (Medenica, Kun, Paek, & Palinko, 2011). During the rear-end collision moment, we evaluate timing and quality aspects. The timing aspects calculated were reaction time, side mirror and indicator. The quality aspects evaluated were the types of reaction and trajectories. *Reaction time* was calculated as the time since 233m TTC until the actual driving maneuver begins, steering wheel angle > 2^o or brake pressure > 10% (Gold & Bengler, 2014; Gold et al., 2013). *Side mirror* was calculated as the time since 233m TTC until the driver glances at the side mirror (Lorenz et al., 2014). *Indicator time* was calculated as the time since 233m TTC until the driver uses indicator (Lorenz et al., 2014). *Types of reaction* was categorized into three groups of interests: braking only, braking and steering or steering only, after receiving the warning (Gold et al., 2013). Trajectories were calculated for 300 m TTC until 100 after obstacle. Finally, collision frequencies were observed during the event of possible rear-end collision. After each lap, the researcher asked the participant to verbally the awareness situation through four questions ("How did you know that AD was activated?"; "What did you see?"; "Where did you see the information?"; "How clear was clear for you understand the information? 1-5 likert scale"). Participants were unaware they would be questioned at the end of the simulation, which allowed for them to attend to the environment as they naturally would in normal driving situations (Endsley, 1995a). These questions had some modifications because the different moments where were used to evaluate the awareness situation, that were: availability, activation, give back and AD deactivated. After each drive, the participants also answered a Van der Laan questionnaire (Van Der Laan, Heino, & De Waard, 1997) as a measure of acceptance of the HMI. This questionnaire was used to evaluate the acceptance of three use case, that were: availability, activation and give back. When considering the usefulness of a system, like the AR, people tend to use or not use an application to the extent they believe it will help them perform their job better (Davis, 1989) and performance gains are often dependent upon the users' level of willingness to accept and use the system. On final interview the participants expressed their preference level by concepts tested through 10-point Likert-type rating scale from "prefer totally a concept" to "prefer totally other concept", showing the images about that specific moment. We evaluate the preference variable in the follow use cases: manual mode, availability, activation, give back and deactivation. On final interview, we also asked the participant to verbally in what concept they felt more trust, through 10-point Likert-type rating scale from 1 - "trust totally in this concept" until 10 "trust totally in other concept", showing the images about the specific moment of both concepts in autonomous and manual mode. We evaluate the trust variable in the follow use cases: autonomous and manual mode. We also solicited qualitative verbal comments about the experiment from participants.

4.6. Data Collection

Sessions were record (audio and video) to be used during data analysis with the purpose of analyzing the participants' feedback about the study. The collection of information maintained and protect the privacy of participants.

Objective data – specific software implemented in the vehicle simulator allow us to obtain several measures of each session. A DataLogger where the entire control area network (CAN) of the vehicle is registered and with a script in Python process those results.

Subjective data – the main source of qualitative data in this study was obtained with the verbalizations, observations, interviews and questionnaires. Appendix 3 – Instructions includes the guides for the researcher in charge of the tests.

- General questionnaire: this questionnaire asks for general information about the participants such as: age, gender, educational level, driving frequency and kilometers driven per year.
- Systematic questionnaire 1: participant answered to questions about the function and the HMI about the specific 'AR concept 'or 'IC concept';
- Systematic questionnaire 2: participant answered to questions about the function and the HMI about the specific 'AR concept 'or 'IC concept';
- Final interview: participant answered to questions about the preference and trust between concepts.

4.7.Technical Description

The technical description explains the user interface (UI) and the simulator used in the user tests.

4.7.1. User Interface

4.7.1.1. How get the User Interface?

The User Interface was designed and developed in Qt Quick and Qt 3D and utilized existing structure within CTAG HMI department that included support for the User Interface used in this study (Instrument Cluster, Central Console and Augmented Reality). All displays are managed by HMI manager that is developed in Python and also uses an existing structure in CTAG HMI. In addition, the Central Console is controlled by touch controls.

The HMI manager receives information from every part of the car (Function, maps, perception, simulator and buttons) from CAN bus, process it and send it to the UI through CAN bus again. The UI process the HMI manager info and shows in the displays the needed information. The HMI manager and the UI software are both inside a car PC that is connected to CAN bus and to the physical displays.

To show all the information necessary in the displays, it's necessary some information in CAN bus, that is:

- **About the objects surroundings**

- Distance to objects (Send by simulator to HMI manager)

- Rail area (x); (Send by simulator to HMI manager)

- Info above about all the objects on road ahead. (Send by simulator to HMI manager)

- **About the time gap**

- Time Gap (s); (Send by function to HMI manager)

- **Car buttons and sensors**

- AD button (Send by simulator to HMI manager)

- Hands on sensors (Send by simulator to HMI manager)

- Pedal sensors (Send by simulator to HMI manager)

- Steering wheel sensors (Send by simulator to HMI manager)

- **Car orientation**

- Orientation car (0 – 360 degrees) (Send by simulator to HMI manager)

- Speed (Send by simulator to HMI manager)

- Current lane (Send by simulator to HMI manager)

- In lane position (Send by simulator to HMI manager)

- **HMI info send by HMI manager to UI**

- Pop ups;

- Notifications;

- Function state;

- Wireframe;

- Concept;

- Obstacle

To develop the UI is necessary many graphical elements. Those are supplied from design department. The inputs that software receives from design are images in ".png" or ".gif" format and its position and behavior in the screen. For example, the AD icon is an ".png" image in "position X, Y" that change color when the driver activates the function and also change his opacity when the Autonomous Driving is available.

4.7.1.2. Augmented reality

The AR screen is projected with a projector Acer P5327W, with a maximum resolution of 1920x1200, located above the car (Figure 14), in the simulator screen, so it can simulate an image in windshield (Figure 15). The resolution of the projector used was 1920x1200 and the simulated image in OA was 763x76 pixels, and in AR area was 725x322 pixels as we can see in Figure 16. The projector is connected to the car PC with a digital visual interface (DVI) connector to video graphics array (VGA) connector converter. The OA is perceived as floating in the air (Figure 17) 10 meters in front of the car on the driver's side and the AR area is perceived as floating in the air 15 meters in front of the car.

In AR area, there is a 3D world that simulates the already existing road. It has the following parameters (Figure 18):

- Position of the camera: (-0,39; 1,055; 0);
- Vertical Field of view (FOV): 15;
- Orientation of the camera: (-0,1º; -5,3º)

A unit (1) in 3D world means a meter in simulator road.

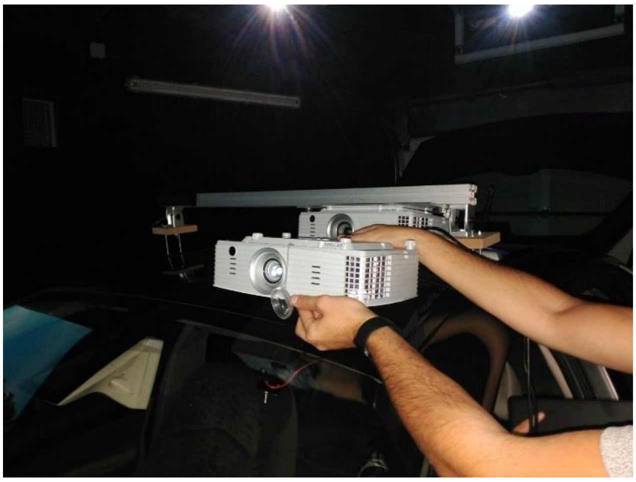


Figure 14 – Physical localization of the projector

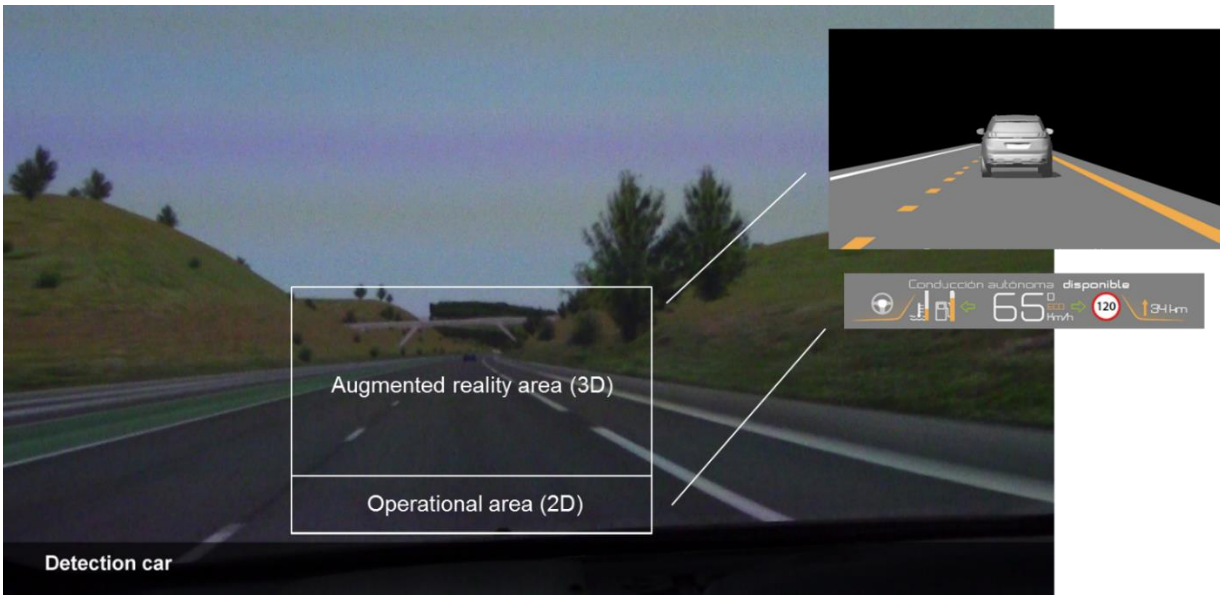


Figure 15 – Vision of the windshield used during the test.

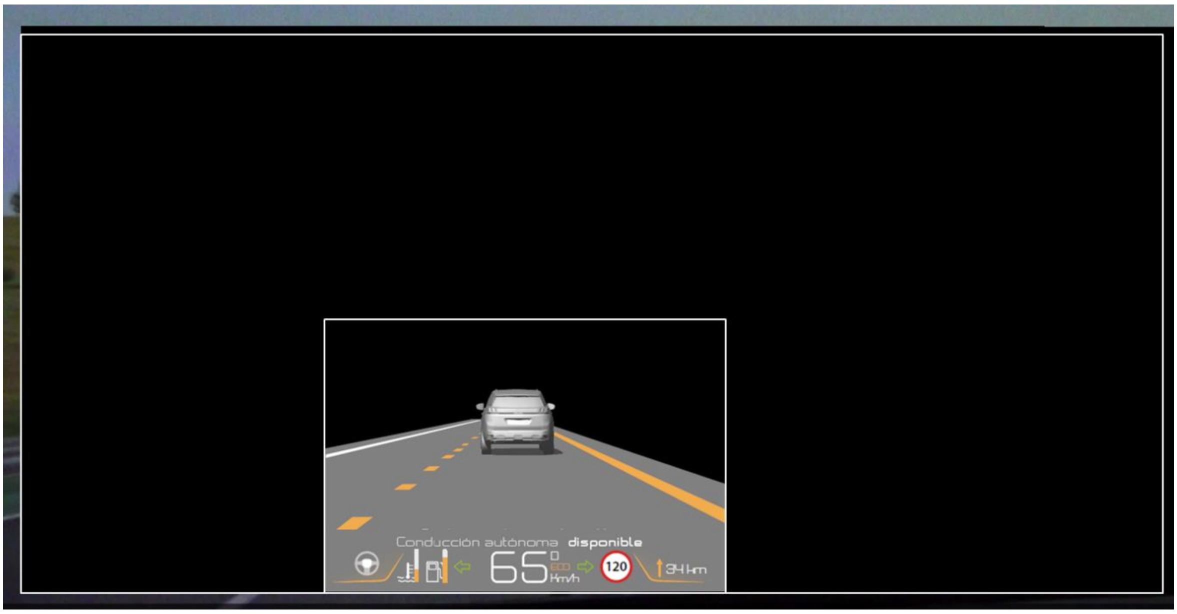


Figure 16 – Projection of the projector on the simulator screen. The black area is the total resolution of the projector. The AR screen is the painted area that the participants saw.

Figure 17 – Real image of AR screen during a test.

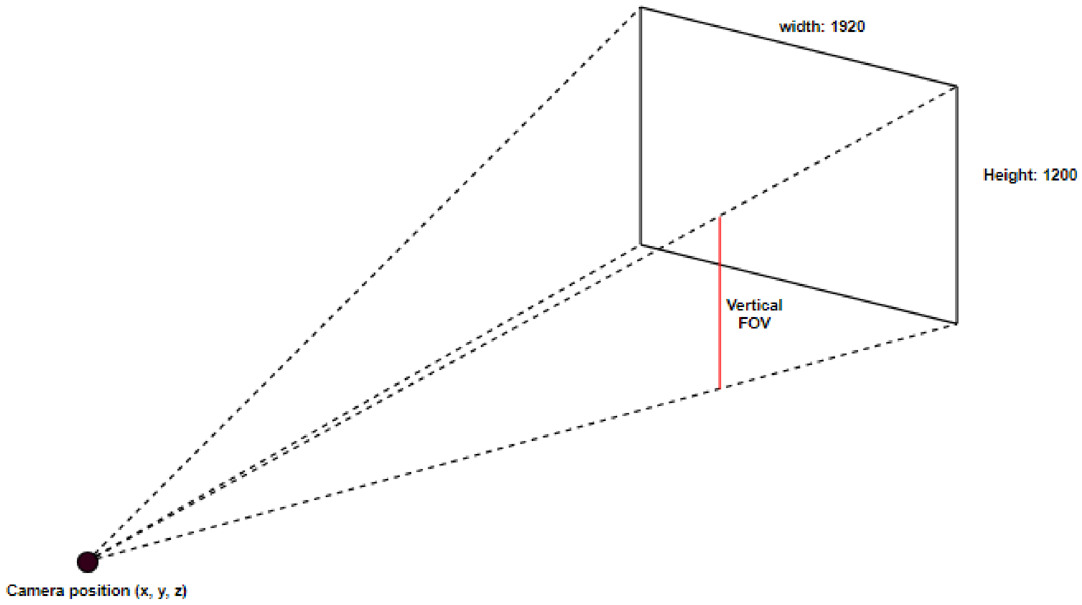


Figure 18 –3D Camera description

4.7.1.3. Instrument Cluster

The IC screen is connected by the DVI connector to the car PC. It has a diagonal of 7 inches and a resolution of 665x400 pixels. The IC screen was located behind the SW (Figure 19).

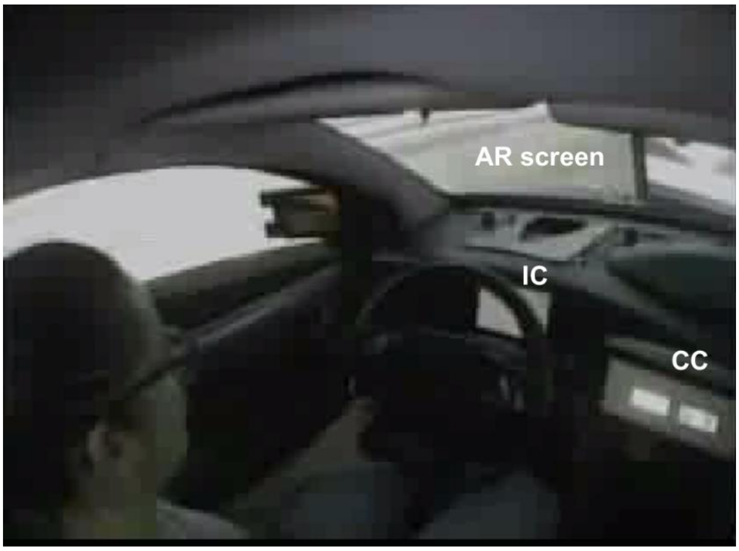


Figure 19 - Displays tested in simulator

4.7.1.4. Central Console

The CC screen is connected by the High-Definition Multimedia Interface (HDMI) connector to the car PC. It has a diagonal of 12,3 inches and a resolution of 1920x720 pixels. The CC screen was in the cockpit, between the driver and the passenger (Figure 19). It has integrated a touch digitizer.

4.7.2. Driving Simulator

In this section, it is describing the CTAG Diving Simulator (Figure 20). This simulator is composed of the following subsystems:

- Movement platform with 6 DOF and 4000 Kg payload.
- Visual system composed by three projectors to obtain a 180º cylindrical screen front view and 3 rear view 7” LCD displays.
- Acquisition and control systems, that contains the following elements:
    - 4 interior cameras.
    - 1 interior microphone.
    - An acquisition software developed by CTAG which records all driving and performance measures during the simulation, synchronized with video and audio data.

- SCANeR© II software, which builds a realistic virtual environment. SCANeR© II tool is complemented with EVARISTE and 3DMax that allow the generation of new 3D database and road networks (road geometry, profiles, new buildings, tunnels, etc.) from real environments with the specific requirements for the simulations.
- The instrumented vehicle inside the cabin. The only changes done in this commercial vehicle were the replacement of the steering-wheel by the Active Steering Wheel System, new instrument cluster composed by a LCD screen, the sensors mounted in pedals and gear stick and the mentioned replacement of rear view mirrors. The vehicle has an automatic gearbox.

Figure 20 – CTAG simulator.

For this test, the following adaptations have been made:

- The road network selected for the study was placed in a highway, without buildings and without curves;
- All the roads used for testing had two lanes in each direction. There was a value of 120km/h for the speed limit and the traffic density was high during the traffic.
- The speed of the traffic was of 45km/h.

4.8.Participants

There were 29 volunteer (19 men and 10 women) from CTAG (Centro Technologic Automation of Galicia) and external participants (Live in North of Portugal and Galicia) tested in this study. Participants needed a valid driver's license, normal or corrected to normal vision, normal color vision and age between 18 and 65 years old to participate in this study. More than 75% of the participants had between 18 and 35 years old, 12% between 36 and 40 years old and 12% between 46 and 50 years old. More than 50% of the participants had more than 10 years of full driver's license, 28% between 5 and 7 years, 12% between 8 and 10 years and only 8% of the participants had between 2 and 4 years of full driver's license. About the traffic accidents, 10/29 participants already had at least an accident, and them, 3/10 had 2 accidents and only a participant had 3 or more accidents. Only a participant (1/29) had HUD in their car and 12/29 participants had experimented an autonomous vehicle before (CTAG simulator).

4.9. Material /Set up

The experiment was developed in CTAG Simulator, with one participant per experimental session. These sessions occurred either during the morning or during the afternoon.

For this experiment, we used the following materials:

- A simulator;
- Four cameras;
- Two tablet;
- Specific data record;
- Specific software;
- A pencil;
- A paper;
- A computer.

4.10. Procedure

In this topic, we described the procedure of the user test (Figure 21). Participants were welcomed to the experimental room and made comfortable. The researcher explained the context of the test, where he said that was an experimental study on static simulator. Also, was explained that the study was part of CTAG research for the autonomous vehicle project (vehicle which can drive alone). After explained the context to the participant, the researcher explained the general objective of the study. The specific objective of the study wasn't explained. He said that the aim of this study was to evaluate the HMI of the traffic situation and the human interaction during an autonomous driving. Participants were then given informed consent and fulfilled a questionnaire with demographic data (Appendix 4 – Sample questionnaire) and provided the opportunity to ask any questions. In informed consent was explained that we needed to collecting data using video cameras that will be filming during all test. The researcher also explained that we had this document as term to guaranty the confidentiality and anonymity of participant data and an inform that participant data could be used on our study and possible presented in some congresses or articles. After participant assign the confidentiality agreement (Appendix 1 – Dato protection; Appendix 2 – Informed consent) was introduced the study's structure, where we presented the instructions and how the system worked (Appendix 3 – Instructions). We explained that the autonomous driving function was based in a situation with traffic jam, speed limit and no lane change. The vehicle drove completely autonomously, it accelerated and braked depending on the vehicle ahead. The participant could make all the activities that they wanted (ex: read a book, used smartphone, …) except sleep. We also said that there was no risk of accident, the vehicle managed everything: speed, steering wheel, obstacles, however, if for some reason the vehicle wasn't not able to manage, it asked him to take the control. We alert the participant that in some moments, the system informed that the autonomous driving function was available for the activation and every time that situation occurred, he should be activated the function with the autonomous driving button. After explained the function, we explained the instructions, telling that the test had two parts: the learning phase, to participant adaptation and to understood the mode and operation of the vehicle, and the drive phase, that constituted the main phase. We said that the duration estimated of the test was approximately 1 hour. During the instructions was also explained that the researcher could ask the participant to make specific secondary tasks during manual and autonomous mode. We explained the participant that there were moments that he/she was in manual mode and others that he was going in autonomous mode. We also said that during the test the system asked him to assume the control. When it happened, he must take over and returned to manual driving, for that, he had to put his/her hands on steering wheel and foot in brake or accelerator pedal.

Participants were told that we would like to know their opinion about driving the car in this study. About the test, we explained that we registered something that they wanted to say us about their experience with autonomous car. Also about the test, we said that we appreciate their opinion as users to improve the system that they tested. Whit this objective, we wanted that the participant comment in loud voice what could stayed in their mind. This could include what they were thinking, doing or feeling.

We asked the participant to try during manual mode drove with a speed of 120 km/h.

Initially, the participants passed a 5-min training to become familiar with the driving simulation. After the preparations, the main test comprised two drives of approximately 10 min each, with a break to answer a questionnaire and to prevent phenomena such as fatigue or simulator sickness from affecting the driving performance. The first drive included two times in autonomous mode and three times in manual mode (explain in more detail in topic 4.10.1). The second drive included two times in autonomous mode and three times in manual mode too, but the last time in manual mode was when happened the specifically use case of possible rear-end collision, explained in more detail in topic 4.10.1. The participant that experimented the AR concept on lap 1, were questioned about that concept during interview 1. By consequence, the lap 2 these participants tested the other concept, IC concept, where they were questioned about IC concept after end of second lap. On final interview, we asked the participant about both concepts together. The participants were counterbalanced between concepts and secondary task to minimize order effects. On final, we acknowledge their participation.

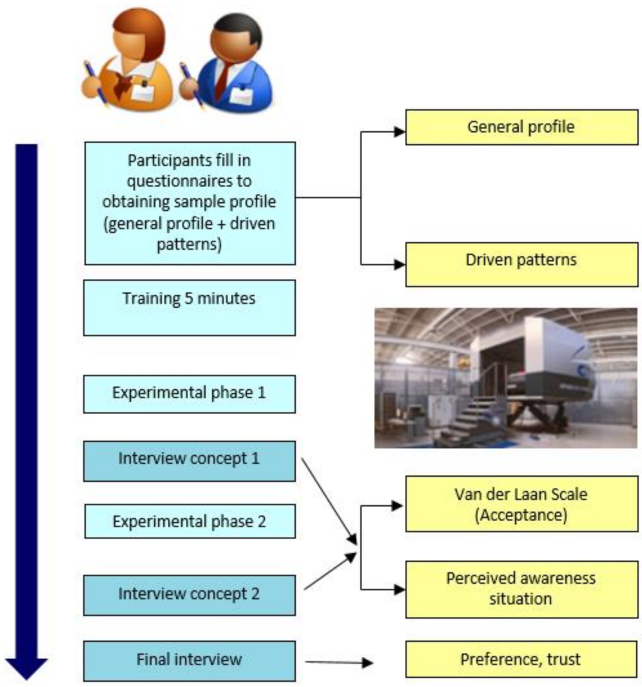


Figure 21 – Procedure.

4.10.1. Scenario

During the session, the participant was always accompanied by a researcher who lead into the simulator and give all the instructions needed. The researcher stays on seat back during all session to help him in case of need and to observe his/her behavior during driving.

The scenario had three "laps": one for learning phase and two for the test phase. The learning phase and the test phase is explaining with more detail in the next topic.

2.8.1.1. Learning phase

This phase (Figure 22) had a duration of 6 minutes and started in manual mode, for adapting to the vehicle, to the track and to the activation process. They also drove in autonomous mode, to understood how the system and the commands worked, disabling the autonomous function. During the learning phase, there were two Give Back (GB). The reason to the GB was normal end of traffic (speed of car in study over 60 km/h) in all cases. The normal end of traffic happened when the car ahead started an increase of speed gradually. Every participant experimented the two concepts during this phase, where 20 participants started with the 'AR condition' and the other 20 participants started with 'IC condition'. We counterbalanced the concepts tested between participants. The participants that started the learning phase with AR concept, started the test phase with the AR concept too. During the second autonomous driving, in learning phase, the experimenter explained the secondary task, explaining to the participant how could to interact with the touch screen to put the movie running in the central console.

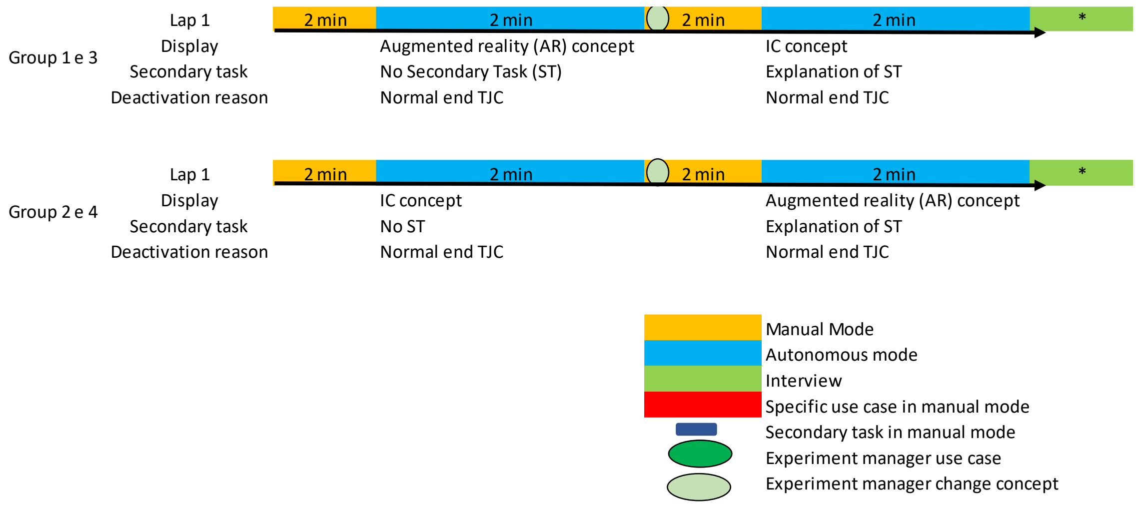


Figure 22 - Learning phase.

2.8.1.2. Test phase

This phase (Figure 23, Figure 24 and Figure 25) had a duration of 30 minutes in simulator and the time of each interview was approximately 10 minutes, but this time depends also on participants. They drove on both ways: manual and autonomous mode, being the moments in manual mode shorter than autonomous. In the manual driving condition, participants were entirely responsible for the manipulation of standard longitudinal (accelerator and brake pedals) and lateral (steering wheel) controls.

In total, there were four Give Backs (GB), all them because normal end of traffic. Also, there were six moments for the secondary task (ST) during manual mode and two during autonomous mode, three for interviews and observations during all the test.

The test phase was composed by two laps. The difference between the participants group was the concept that tested first and the order of secondary task. We counterbalanced the independent variables, that was, the display and the secondary task in autonomous mode. The group 1, Figure 23, tested first the AR concept and by consequence, the first part of the interview was just about the AR concept. The Group 2, on lap 1, tested the IC concept first. On lap 2, the group 1 and 2 tested the other concept that didn't test on lap 1. The second time to interview was about the second concept tested. The final interview was a comparison between concepts, where the purpose was to know the user preference and trust between concepts. The difference between group 1a and 1b, 2a and 2b, 3a and 3b, 4a and 4b were the order of secondary task in autonomous mode (Figure 24 and Figure 25). The difference between group 1 and 3 was the last use case, a group received the forward collision warning (group 1) and the other group didn't receive warning (Group 3 – baseline AR concept). The difference between group 2 and 4 was the last use case, a group received the forward collision warning (group 2) and the other group didn't receive warning (Group 4 – baseline IC concept). There were moments that the experimenter asks to the participant do the secondary task. After the driver put the movie in the place that the experimenter asked, there was no more interaction with the central console.

About the last time in manual mode, in lap 2, the warning was triggered by the driving simulation when the participant's car exceeded a predefined time-to-collision (TTC) threshold of 7 seconds to car ahead and potential collision opponent (Figure 26). The obstacle appeared suddenly to make sure the time budget would be the same for all conditions (Radlmayr et al., 2014). The obstacle appeared in a current lane and becomes visible to the participant which corresponded to a TTC of 7 s (=233 meters at 120km/h) (Lorenz et al., 2014; Radlmayr et al., 2014). Participants could prevent a collision by braking and/or performing a lane change. Obviously, repeating the same scenario several times would eliminate the potential effect of warning, as the participants would remember the type and the position of a recurring hazard, for that we made a design between subjects.

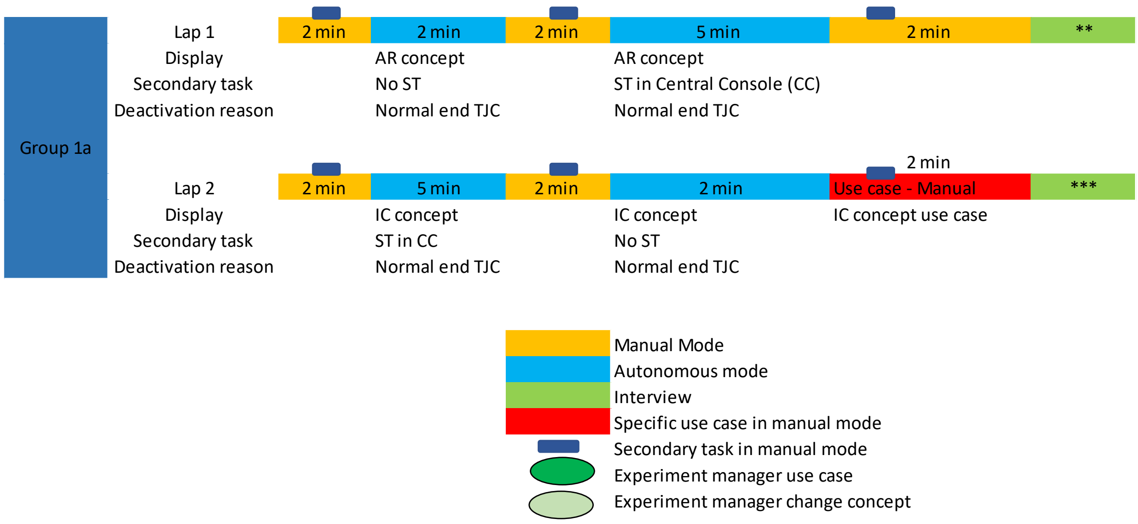


Figure 23 – Test phase, Group 1a.

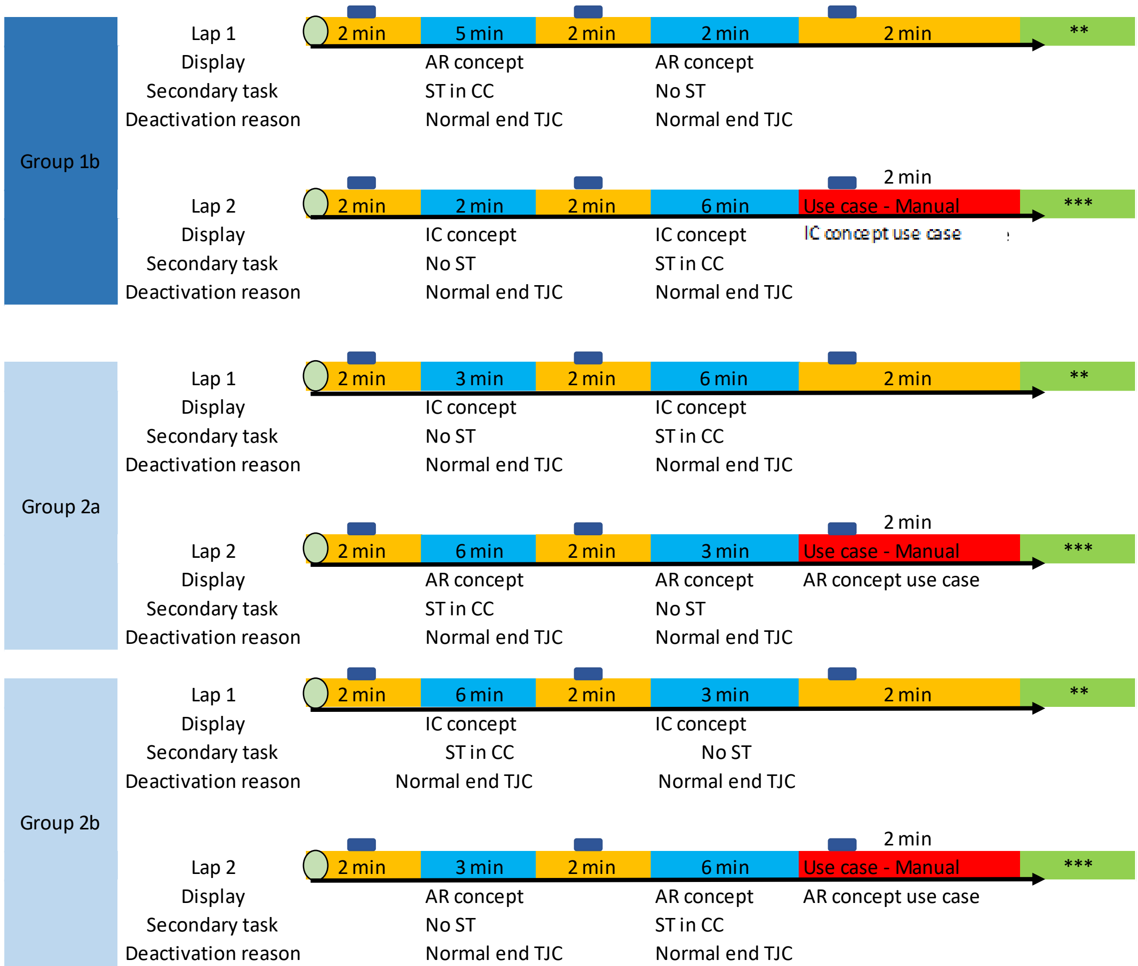


Figure 24 - Test phase group 1b, 2a, 2b

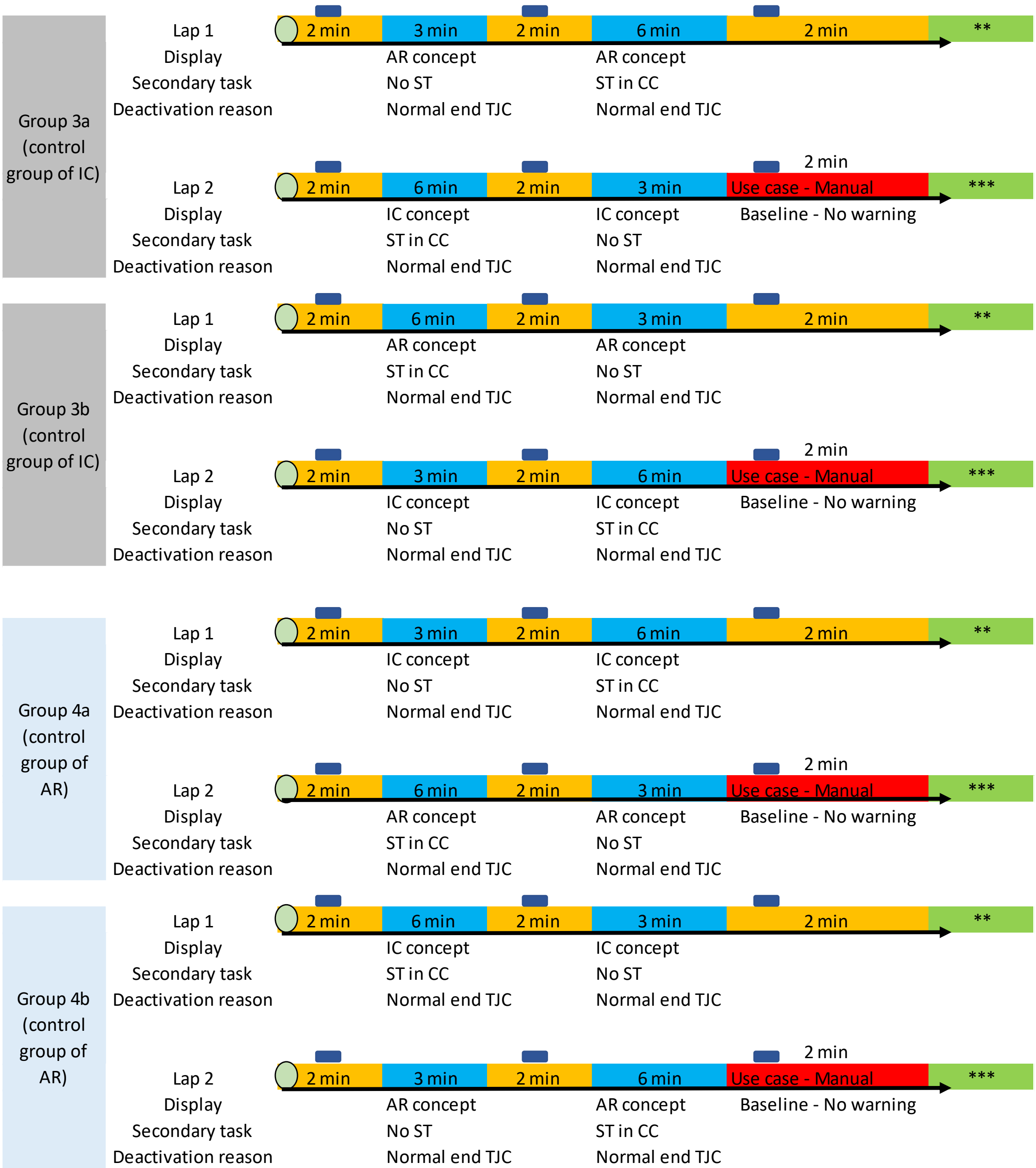


Figure 25 – Test phase group 3a, 3b, 4a and 4b.

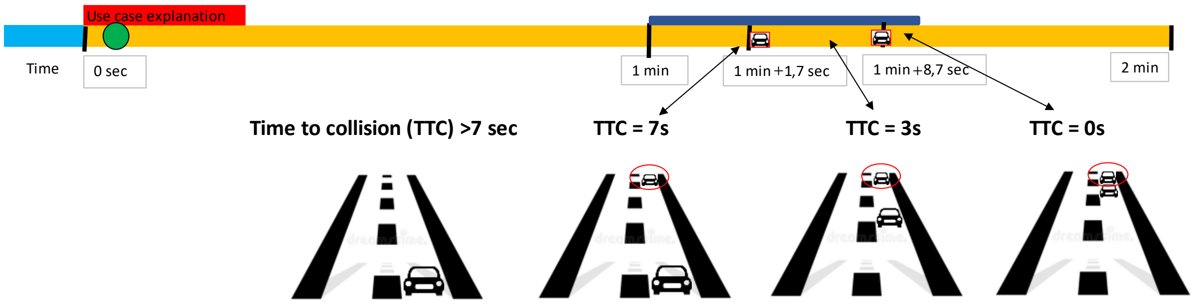


Figure 26 – Use case of possible rear-end collision.

5. Results

In this topic, we will present in detail the results of manual mode, availability, activation, autonomous driving activated, give back, deactivation and rear end collision. Before that, we can see in Table 2 the summary of results obtained in each moment tested. In terms of preference, "AR concept" showed significant difference in all the moments when comparing with "IC concept". Confidence showed better results to "AR concept" too. The participants were more aware in "AR concept" during availability and activation moment, however during the give back and deactivated moment, the results showed no significate difference between concepts. "AR concept" showed be more useful significantly in availability and activation moment. During the give back, the results showed no significate difference. In terms of satisfaction, only during activation the results showed significate difference between concepts, favoring "AR concept". In terms of reaction time and behaviors, the results showed no significate difference between concepts during the give back. During the giveback, the behavior was safer in "AR concept", however the reaction time was better in "IC concept".

Table 2 – Summary of results.

	Preference	Confidence	Awareness situation	Usefulness	Satisfaction	Timing aspects	Reaction types
Manual Mode	AR (P<0,05)	AR 72% vs IC 22%	-	-	-	-	-
Availability	AR (P<0,05)	-	AR (P<0,05)	AR (P<0,05)	No validate	-	-
Activation	AR (P<0,05)	-	AR (P<0,05)	AR (P<0,05)	AR (P<0,05)	-	-
Activated	-	AR 76% vs IC 10%	-	-	-	-	-
Give Back	AR (P<0,05)	-	No difference (p>0,05)	No difference (p>0,05)	No difference (p>0,05)	No difference (p>0,05)	No difference
Deactivation	AR (P<0,05)	-	No difference (p>0,05)	-	-	-	-
Rear end collision	-	-	-	-	-	IC	AR

5.1. Manual Mode

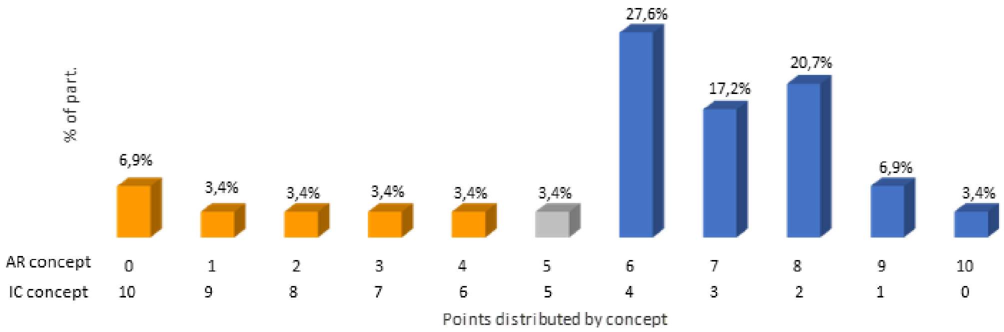
In manual mode, we evaluated the preference and confidence between concepts.

Preference

The participants, seeing the image of both concept on the final interview, had to distribute 10 points between the two concept according with the concept preferred, where the sum of points must be 10 (Appendix 8 – Final interview). Graphic 3 shows the points distributed by participants in each concept according the preference of display during manual mode.

Looking at the Graphic 3, more than 75% of the participants (22/29) preferred the AR concept, 3,4% of the participants (1/29) didn't prefer anyone and approximately 24% of the participants (6/29) preferred IC concept. The mean value that the participants gave to AR concept was 6,00 points (SD = 2,605 points) and to IC concept was 4,00 points (SD = 2,605 points) (Table 3). The Wilcoxon analyses showed significant difference when comparing the preference between concepts (Z = -2,030, p = 0,021) for an α=0,05, so it is to be admitted statistically that the participants prefer "AR concept" comparatively to "IC concept" during manual mode.

Table 4 shows the reasons presented by participants after distributed the preference points to each concept. The participants with negative response to AR concept (<5 points preference to AR concept) gave like main reasons that they were accustomed to IC, it's easier drive without lines and the information in IC was more visible (Table 4). The participant that didn't prefer any concept (=5 points preference to each concept) argued as main reasons that option AR was more effective, however the IC option had a better design and If he must have bought a car, he had bought the option IC because he was more used to it (Table 4). The participants that preferred AR concept (>5 points preference to AR concept) argued as main reasons that they were more comfortable in AR option because didn't need take the eyes of road, they had everything necessary in windshield, they argued too that didn't miss the IC, they felt disoriented when tried look to IC during the test, that the information on windshield allow you to increase the trust, that information avoid that you stayed distracted and that appears right what you needed in windshield. The lines were seen more negative than positive by most of participants.



Graphic 3 – Percentage of participants according with the points distributed by concept about the preference during Manual Mode.

Table 3 – Descriptive statistics about the preference in specific moment of Manual Mode per concept

	AR Concept			IC concept		
	Mean	**Min - Max**	**N**	**Mean**	**Min - Max**	**N**
Availability	6,00 ± 2,605	0 - 10	29	4,00 ± 2,605	0 - 10	29
Significate difference	Z = -2,030, p < 0,021					

Table 4 - Reasons about the preference by a concept in the specific moment of Manual mode.

Points Distributed by concept		**Transcription participants comments**
IC	**AR**	
0	10	"I didn't look to the IC when I tested the option IC, only to the OA. I felt me disoriented when look to the IC, so I don't know what happens here (IC). When I try focus in IC, didn't appeared nothing. It's more comfortable AR option because isn't necessary take my eyes of road"
1	9	"Because I have everything that I need in manual mode in option AR. I didn't miss the IC, I didn't look to there"
1	9	"I consider that is very important keep with eyes on road. I think that is superfluous the temperature and fuel information in OA. Don't seems fundamental show that information always. I didn't miss the IC."
2	8	"Because I can see clearer, I am looking to the road and I can see the information. For me the car should to have both screens, however if I have only one, I want the option AR. I didn't miss the IC."
2	8	"Because the lines. The temperature and fuel it's ok but you don't need see during all the time. I miss the IC, but the information in OA made up for it."
2	8	"In windshield seems more useful because I don't need look down to the IC. I didn't miss the IC"
2	8	"Because have the information closer to the eyes (on road). The information more important appears on road."
2	8	"Because I like a lot don't have to look down... it's more comfortable appears the info in AR screen. But is never so much show info in IC. After 2 minutes, I didn't look to the IC again."

Points Distributed by concept		Transcription participants comments
IC	AR	
2	8	"Because seems better have everything in only 1 display. It bothers me to go down with my eyes to manage the speed and in AR option you have everything in your field of view"
3	7	"I liked to have the information without having to look at the IC. Seems more useful and allow you increase the trust"
3	7	"It's complicated. The lines didn't help me so much but I felt more comfortable with AR option. I felt more comfortable because I was driving, and when I am driving I look to the road, so the information appears there and no limit my vision. Help you because you don't need change the eyes, you keep your attention in the road and you obtain the information that you intend. I will buy the option AR, with the option of put lines when I want. With the time, I think that I will get use to the lines, but now it's usefulness"
3	7	"Seems more useful and distract less appears the information in AR screen, in summary because the comfort and clarity."
3	7	"Because the AR area facilitate, I don't have to look down to the IC. The OA don't give me much information"
3	7	"Because the information in windshield avoid that you stay distracted. In Option AR I will change the position of fuel and temperature to another place, not in windshield"
4	6	"In option IC I have a lot of information… in option AR appears right what you need… however the lines in Opt AR make some confusion because I am not get used to it. And these lines distract me a lit bit because they were in movement. So, I prefer the option AR because the OA. I miss a little bit the IC, sometimes I looked to there... seems strange that didn't appear nothing there but I am ok with only OA"
4	6	"In manual driving the lines didn't give nothing… the OA it's good. Bothers me I didn't have information in IC. I would like to have the information repeat in IC… Coast less to see the information in OA. For me the lines are better detected in IC than in OA."
4	6	"Option AR safer, however aesthetically a preferred option IC"
4	6	"Because with lines I felt safer. The fuel and temperature icon don't should appears in OA. That information should appear in IC. The lines in excess can arrive to molest"
4	6	"I don't give more points to option AR because distract me. I prefer AR option because how appears everything on road, I didn't distract me and with IC I had to take my eyes of road. I didn't miss the IC"
4	6	"It's more comfortable to see. Seems that I have less data in option AR".
4	6	"Because the OA, it's the first place that I look when I need something. I didn't miss the IC. I don't like the lines in manual mode. I gave 4 points to OPT 1 because is what I get used to".
4	6	"Because I don't need take my eyes of the road. I miss the IC because I am get used to it, but with AR option I felt less distracted. I drove in the normal way with information on road"

Points Distributed by concept		Transcription participants comments
IC	AR	
5	5	"The option AR is more effective. However, the option IC has a better design. If I must buy a car, I will buy the option IC because I am more get used to it."
6	4	"I will add both options. Nowadays I prefer the IC option, because I need that. If I consider the assistance to the driver, I will prefer option AR"
7	3	"I am get use to IC and it's easier to drive without lines. In option IC, we should to have OA"
8	2	"Because I get use to IC"
9	1	"It's more visible de IC"
10	0	"Because I don't like the lines. But without lines, the OA it's ok. In option IC, I didn't see the cars anyway. In IC I just fixed me in speed and colors"
10	0	"Because I am get use to have IC. When I started, the lines made me confusing"

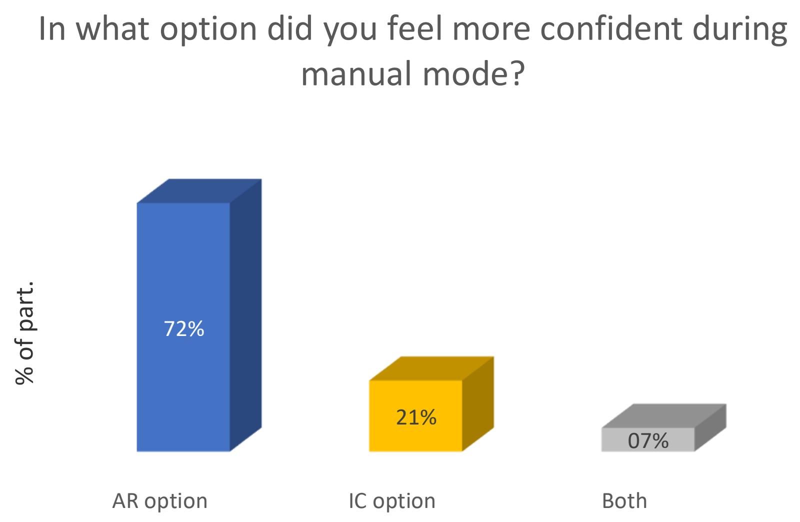
Confidence

Graphic 4 shows the display where the participants felt more confident during manual mode. Looking at the Graphic 4, more than 70% of the participants felt more confident in "AR concept", 7% of the participants didn't feel difference in terms of confidence between concepts and 21% of the participants felt more confident in "IC concept".

We can see in Table 5 the reasons present by participants to feel more confident in a concept or in other. The main reasons presented by participants to feel more confident in "AR concept" were that the information appeared at hand, there wasn't need to change the view of road, it's easier to adjust the speed, easy to use the information in windshield, less distractions, because the lines and personal problems when nowadays they try got information of IC in their own cars (Table 5).

The main reasons presented by participants to feel more confident in IC concept were that AR option it impeded me to see the depth of the horizon, gave me more safety because I use the screen (IC) like a confirmation, because they were get used to IC, that the lines seem a video game and that they preferred to receive less information on road (Table 5).

The main reasons presented by participants to didn't differentiate the confidence between concepts were because the HUD is the first place that I look when I need something and appeared in both options (Table 5).



Graphic 4 - Percentage of participants according with the concept where they felt more confident during Manual mode

Table 5 - Participant comments about the reasons to feel more confident in AR concept, in IC concept or in both during Manual Mode

AR Concept	IC concept	Both
“Because I had less distractions”	“Because in AR option it impeded me to see the depth of the horizon, seems that the road becomes narrower”	“Because the HUD is the first place that I look when I need something and appear in both options”
“Because I was looking to the road, I had the information at hand"	“Gave me more safety because I use the screen (IC) like a confirmation and maybe because I get used to it”	
“Because the lines”	“Because the lines make me drive worst”	
“Because appeared the lines in windshield, so was easier I guide me in the lane. I was more attentive to the speed and was easier to adjust the speed. I didn't need to change my view of the road”	“I am get use to IC. The AR option seem more like a videogame. Seems that I will hit easier. I am not a person of videogames”	
“Information appears closer of the eyes”	“Because I prefer to have less information on road”	
“Because the comfort of appears the information in AR screen”		
"I find it comfortable have the possibility to keep my eyes on the road"		
“It's more comfortable AR option because wasn't necessary take my eyes of road”		
“You can keep with your eyes on the road. I sometimes have some problems when try to see the fuel level in IC nowadays”		
“Because I felt more comfort and clarity in the information”		
“It's easier to understand the signs”		
“Because give much more information! (mainly the lines and car mark). I didn't miss the IC, in my own car I almost don't use the IC. If am tired, with the lines I will feeling better”		

AR Concept	IC concept	Both
"Because I reduced the time to obtain the visual information because the info appeared on the road. I saw very compatible, was very easy to adapt"		
"Because you didn't need change the view."		
"Because I saw the lines, I had more help"		
"The info was clearer. The option AR gave me an add value because the information appears closer to my eyes, I can maintain my eyes on road"		
"I saw everything where I was looking and the other option made take the eyes of road"		
"It's more intuitive to see and didn't force me to take my eyes off"		
"Because I was more entertained and gave more safety. In IC option the car didn't see the environment"		
"Because the information appears already on the road"		
"Because I always can keep with eyes on road"		

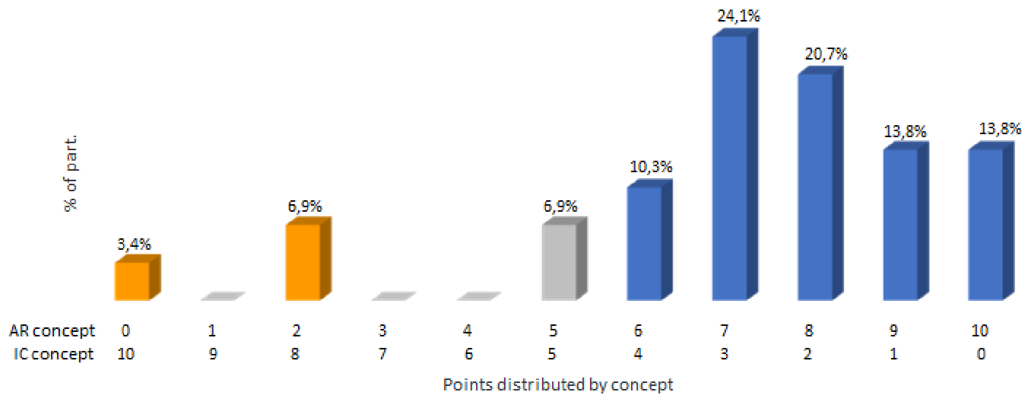
5.2. Availability

During availability moment we evaluated the preference, acceptance and awareness situation, comparing both concepts.

Preference

Graphic 5 shows the points distributed by participants in each concept according the preference of display during availability moment.

Looking at the Graphic 5, more than 80% of the participants (24/29) preferred the AR concept, 6,9% of the participants (2/29) didn't prefer none and only approximately 10% of the participants (3/29) preferred IC concept. The mean value that the participants gave to AR concept was 7,07 points (SD = 2,448 points) and to IC concept was 2,93 points (SD = 2,448 points) (Table 6). The Wilcoxon analyses showed significant difference when comparing the preference between concepts ($Z = -3{,}264$, $p < 0{,}001$). So, it is to be admitted statistically that the participants prefer "AR concept" in the specific moment of availability comparatively to "IC concept". We can see on Table 7 the reasons presented by participants after gave the points to each option. The participants with negative response to AR concept (<5 points preference to AR concept) gave like main reasons that the information that appeared in OA was too small and that the lines in AR area provoked disturb (Table 7). The participants that didn't prefer any concept (=5 points preference to each concept) argued as main reasons that they would like to have both options and that the most important in this moment was the sound (Table 7). The participants that preferred AR concept (>5 points preference to AR concept) argued as main reasons that they found the visual information faster, in the field of view and some participants said that the information was easy to see (Table 7).



Graphic 5 – Percentage of participants according with the points distributed by concept about the preference about AD available.

Table 6 – Descriptive statistics about the preference in specific moment of availability per concept

	AR Concept			IC concept		
	Mean	**Min - Max**	**N**	**Mean**	**Min - Max**	**N**
Availability	7,07 ± 2,448	0 - 10	29	2,93 ± 2,448	0 - 10	29
Significate difference	Z = -3,264, p < 0,001					

Table 7 - Reasons about the preference by a concept in the specific moment of availability.

Points Distributed by concept: IC	Points Distributed by concept: AR	Transcription participants comments
0	10	"It's more comfortable AR option, I didn't care about the information below. In Option IC, I only remember the voice, in option 2 was everything."
0	10	"I listen the sound and quickly I obtain the text information. In option IC, sometimes I didn't see visual information about this moment. I will increase the size of text and aesthetically I will improve the design of lines. Make more game with the lines to help the driver to know the distance to the car ahead."
0	10	"I achieved the information faster and I liked more."
0	10	"In both option the first help was the sound, after I search info in the road, so I saw first the information in AR option than in IC option, that I had to take my eyes of road."
1	9	"Because you are looking to the road, so you don't need move the eyes. I didn't see the icon. I saw the text because the sound. The message could appear with a size bigger and with some flicker."
1	9	"I saw clearer the message in HUD after I listen the sound."
1	9	"Because in case of noise, the visual information in HUD is very clear."
1	9	"Because the info appears where I was looking."

Points Distributed by concept		Transcription participants comments
IC	AR	
2	8	"Happen a lot of things in option IC, the icon was difficult to see because the position of SW and the message I just saw the word "Available" and in option AR, the information was more directly… because there are less elements in the HUD. I never tested this in a real car, but seems me comfortable."
2	8	"Because the info it's closer of my eyes."
2	8	"Because the information appeared closer to the eyes (on road)"
2	8	"Because appears directly in HUD the text. I would like to have the information duplicated in the IC"
2	8	"When there is more alert of this type, should appears in windshield, appears closer to the eyes"
2	8	"I saw better the option AR. In option IC, I searched and I only saw an icon. In AR option the information was simpler."
3	7	"Because appeared in the windshield, after I listen the sound, if I look to the IC, I am distracted, so option AR it's ok"
3	7	"Because I can see everything in option AR in an easy way. For example, the temperature and fuel I prefer the design of IC… I would like to have this design in HUD… maybe on the right part"
3	7	"I find it comfortable have the possibility to keep my eyes on the road"
3	7	"Now I can see that there is a permanent feedback, however wasn't clear for me, neither effective nor efficient. Maybe if I receive some previous help about this will be more intuitive… I can keep with the eyes on the road. If am driving with music aloud, maybe I can't understand that AD was available without take my eyes of the road"
3	7	"Easier to interpret"
3	7	"For IC I only look x times, however to HUD I was always looking"
3	7	"Appeared *in front of the noses*, so it's easier"
4	6	"The most important was the sound. The message in option AR appeared closer to the eyes"
4	6	"What was more important was the sound… make me search and there the place more comfortable to check the info is the HUD. But the text in HUD wasn't easy to read"
4	6	"Because the information appeared already on the road. It's a new information, so is better appears on the road. If possible, for me the lines didn't should appeared during manual mode"
5	5	"I would like to have both options"
5	5	"Because what help me more was the sound. I put the same points because I can't compare information that I didn't see (IC visual info)"
8	2	"Because 'yes'"
8	2	"The icon of AD doesn't seem it. Seems an icon that means proximity. I gave two points to option AR because the HUD. I can't stand the lines. To see the speed, I prefer the HUD"
10	0	"Because in the option AR, the car info that appeared in HUD was small y few visible. It's out of sight"

Acceptance

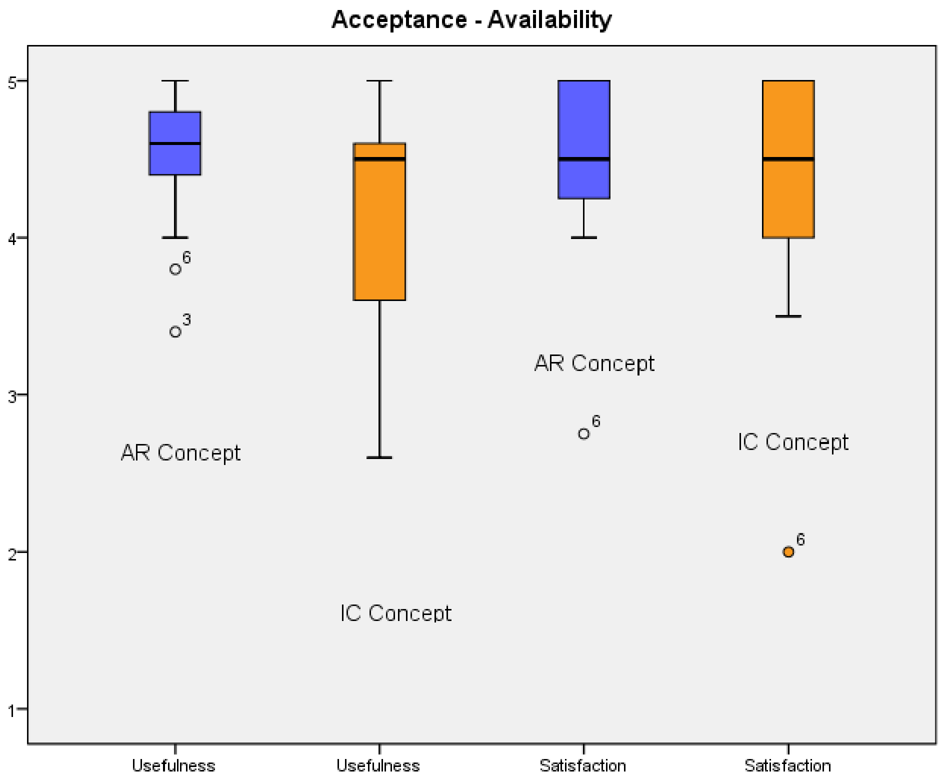
Reviewing data analysis showed that there were five participants in the "AR" concept, and eight in the "IC" concept who mix the availability moment with other moment by comments. Since all participants should be awareness of this moment, we did not consider these five and eight participants for the analysis. Finally, the used sample consisted of 24 participants in AR concept and 21 participants in IC concept.

Graphic 6 shows the boxplot of the points distributed by participants to the 9 items of Van der Laan questionnaire, already divided in usefulness and satisfaction according the concept tested, during availability moment. Table 8 shows all means, maximum, minimum and standard deviation of acceptance to the two concepts tested in the same moment.

Looking at the Graphic 6, we can to see that seems there is difference between the opinion about the usefulness between concepts, being more positive to "AR concept". On Table 8 we can see that the mean value of the usefulness opinion in both concepts is very positive, close to 4,5 points, in a scale the 1 until 5. The Wilcoxon analyses confirms the information obtained in Graphic 6, showing significant difference when comparing the opinion of usefulness between concepts (Z= -2,909, p=0,001) for an α=0,05. So, it is to be admitted statistically that the participants consider more useful "AR concept" comparatively to "IC concept" in the specific moment of availability.

Relatively satisfaction variable, looking at the Graphic 6 again, seems there isn't difference between groups, however is possible to see more variation in IC concept. In Table 8 we can to see that the IC concept has a minimum value under the AR concept, but both mean values are good (4,47 and 4,32 respectively). The Wilcoxon analyses showed no significant difference when comparing the opinion of satisfaction between concepts (Est=-1,208, p=0,120) for an α=0,05.

During the acceptance questionnaire, when the participants didn't answer 'positively', the experimenter asked the participant what was the reason or what could to miss for be better. Table 9 shows the comments about the AR concept. We can highlight to the usefulness a design problem (the size of the text in OA) and a engineer problem (the delay after the driver press AD button) as influencing negatively the driver responses (Table 9). About the satisfaction variable, we can highlight the text again, as well as the lines in AR area influencing the negative responses (Table 9). Table 10 shows the comments about the IC concept. We can highlight to the usefulness that some participants missed the AR concept, and some participants mentioned that didn't see the icon and text about this moment, influencing negatively the driver responses Table 10. About the satisfaction variable, we can highlight that the visual information wasn't perceived, influencing the negative responses (Table 10).



Graphic 6 - Boxplot of acceptance variable by concept in the specific moment of availability

Table 8 - Distribution of the sample according with the usefulness and satisfaction in the availability moment

	AR Concept			IC Concept			Significate difference	
	Mean	**Min - Max**	**N**	**Mean**	**Min - Max**	**N**	**Est**	**p**
Usefulness	4,52 ± 0,48	3,4 – 5	24	4,11 ± 0,73	2,6 - 5,0	21	- 2,909	0,001
Satisfaction	4,47 ± 0,51	2,75 – 5,0	24	4,32 ± 0,73	2,0 – 5,0	21	-1,208	0,120

Table 9 - Comments during the Van der Laan questionnaire when negative answers about the availability moment to AR concept.

<table>
<tr><th>Usefulness</th><th>Satisfaction</th></tr>
<tr><td>Useful |__| X |__|__|__| Useless – “Miss something that call more my attention”;</td><td>Pleasant |__ | X |__ |__|__| Unpleasant – “The words are too small. Maybe in bolt will be better”</td></tr>
<tr><td>Bad |__ |__ |__| X |__| Good - "If the driver is listening music (Radio), the sound should decrease to the driver listen the availability sound”</td><td>Pleasant |__ |__ | X |__|__| Unpleasant – “It's not easy read the text. With sound it's ok, but in an environment with more sound I don't know”</td></tr>
<tr><td>Effective |__|__|X|__|__| Superfluous - "It’s a little small the text"</td><td>Nice |__|__|__| X|__| Annoying - "Because the lines"</td></tr>
<tr><td>Effective |__|X|__|__|__| Superfluous -"After I press the button and appears the information, there was some delay, so I would like a quickly response"</td><td></td></tr>
</table>

Table 10 - Comments during the Van der Laan questionnaire when negative answers about the availability moment to IC concept.

Usefulness	Satisfaction
Useful |__| X |__|__|__| Useless – "I liked more the other option";	Pleasant |__|__|__|__| X | Unpleasant – "Because I didn't notice that"
Useful |__| X |__|__|__| Useless – "I miss the information in AR Screen"	Undesirable |__ |__ | X |__|__| Desirable – "Maybe in the future, only visual will be fine"
Useful |__| X |__|__|__| Useless – "Sound very useful but the message and icon I don't consider useful because I didn't see"	
Useful |__|__ | X |__|__| Useless – "I need more visual information"	
Bad |__ |__ | X |__ |__| Good - " I didn't see the icon"	
Effective |__|__|X|__|__| Superfluous - " Don't call much my attention "	
Effective |__|__|X|__|__| Superfluous – "Sound yes, visual no"	
Effective |__|__ |__| X |__| Superfluous -" Too much info"	

Awareness situation

Table 11 shows the responses for the 4 questions that we used to ensure the awareness situation during availability moment. The first question was how they knew that the AD function was available. In both concepts, what help their more were the sound (argued by 83% in "AR concept" and 82% in "IC concept"), followed by the message "AD available" (mentioned by 71% and 54% participants, respectively). The icon was noticed by only 13% of participants in "AR concept" and 14% in IC concept. 4 participants associated this moment to a "change of color" in IC concept and a participant in "AR concept".

Then, we asked more specifically, what the participant saw in this specific moment and to both concepts, the message "AD available" was the information more seen (mentioned by >75% in both concepts), followed by icon that was seen by less than 1/3 of the participants in both concepts (28% and 19% respectively). Other items were identified by few participants (less than 8% of participants), as the white color and the lines in yellow.

About the place where the participants saw the information, to the “AR concept“, all the participants identified that the information appeared in Operational Area (OA), however around 20% of participants didn’t identified the correct place, mentioned that appeared in AR area. In “IC concept”, most of participants identified the IC as the place where appeared the information, however 2 participants didn’t see any information and 2 participants said incorrectly that appeared on the road, in OA.

The last question about this moment was how clear was to the participant understand that AD was available. The participants had a Likert scale with 5 points to answer to this question, where the 5 was the most positive (“Very clear”), and by consequence the 1 the most negative (“No clear”). In both concepts, most the participants answer positively, however 76% of participants in “AR concept” gave the maxim punctuation, against 36% in IC concept. The Wilcoxon analyses showed significant difference when comparing the clarity to understand the information between concepts ($Z = -3{,}066$, $p < 0{,}001$) for an $\alpha=0{,}05$. So, it is to be admitted statistically that the participants understood better that AD was available in “AR concept”, comparatively to “IC concept”.

In this last question, when the participants didn’t answer ‘very clear’, the experimenter ask to the participant what was the reason or what could to miss for be ‘very clear’. Table 12 shows the reasons of the negative response. We can highlight that to “IC concept” the negative comments were about the position of information in IC, the time that appeared the text and the size of information. In “AR concept”, the negative comments were because the size and the quantity of information that appeared.

Table 11 – Characterization of the sample according with the awareness situation on the specific moment of availability.

Availability of TJC		**AR concept**		**IC concept**	
		N	%	N	%
How did you know that AD was available?	Sound	20	83,3	23	82,1
	Message "AD available"	17	70,8	15	53,6
	Icon	3	12,5	4	14,3
	Change of color	1	4,2	4	14,3
	Change the lines	1	4,2	0	0
	Low speed	1	4,2	0	0
	Vibration in SW	0	0	1	3,6
	Indicator	0	0	1	3,6
What did you see?	Message "AD available"	22	88,0	20	76,9
	Icon	7	28,0	5	19,2
	Change of color	4	16,0	3	11,5
	Some text	2	8,0	2	7,7
	Lines in yellow	2	8,0	0	0,0
	Vibration	1	4,0	0	0,0
	White color	0	0,0	1	3,8
	Indicator	0	0,0	1	3,8
	Blue color	0	0,0	1	3,8
Where did you see the information?	OA	20	80,0	2	7,1
	AR screen	3	12,0	0	0,0
	AR area	2	8,0	0	0,0
	IC	0	0,0	24	85,7
	Nowhere	0	0,0	2	7,1
How clear was for you to understand that AD was available? *	1 (No clear)	0	0,0	0	0,0
	2	0	0,0	3	10,7
	3	3	10,3	1	3,6
	4	4	13,8	12	42,9
	5 (Very clear)	22	75,9	10	35,7
Significate difference	Z= -3,066	P<0,001			

Table 12 – Participant comments about the clarify of availability moment.

Question	AR Concept	IC concept
*	"Because the size of information. Maybe a light in the SW would be useful" --ID17	"Because appears in the IC but you aren't going to fix there" -ID17
*	"Few information" – ID2	"Miss me visual information. It's a bad position and with a small size" – ID19
*		"Time of message too short. The text shouldn't disappear" – ID30

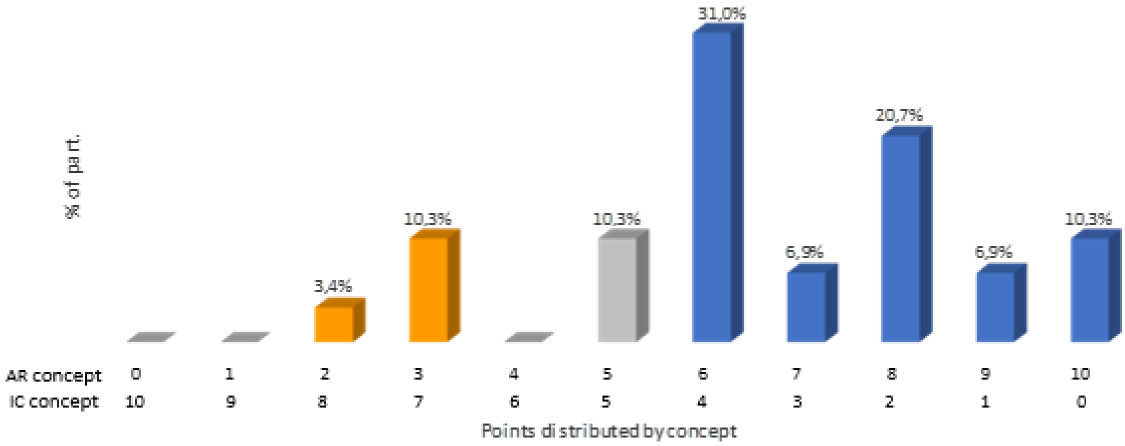
5.3.Activation

During activation moment we evaluated the preference, acceptance, awareness situation and confidence, comparing both concepts.

Preference

Graphic 7 shows the points distributed by participants in each concept according the preference of display during activation moment.

Looking at the Graphic 7, more than 75% of the participants (22/29) preferred the “AR concept”, 10% of the participants (3/29) didn’t prefer none and only approximately 14% of the participants (4/29) preferred “IC concept”. Table 13 shows all the means, maximum and minimum of preference of two concepts tested. The mean value that the participants gave to “AR concept” was 6,55 points (SD = 2,148 points) and to “IC concept” was 3,45 points (SD = 2,148 points) (Table 13). The Wilcoxon analyses showed significant difference when comparing the preference between concepts ($Z = -3,111$, $p < 0,001$) for an $\alpha=0,05$. So, it is to be admitted statistically that the participants prefer “AR concept” in the specific moment of activation comparatively to “IC concept”. We can see on Table 14 the reasons presented by participants after gave the points to each option. The participants with negative response to “AR concept” (<5 points preference to “AR concept”) gave like main reasons that in IC could see the car information bigger, the most important was the change to blue color and that was more visible in IC and because the participant don’t like receive information on road (Table 14). The participants that didn’t prefer any concept (=5 points preference to each concept) argued as main reason that the most important was the color, and that was visible in both concepts (Table 14). The participants that preferred “AR concept” (>5 points preference to AR concept) argued as main reasons that the AR concept gave more trust that AD was activated, because they didn’t look to IC during driving, that the driver can see the same that the AD is seeing and because appears where the driver is looking in a comfortable way (Table 14).



Graphic 7 - Percentage of participants according with the points distributed by concept about the preference about AD activation.

Table 13 - Descriptive statistics about the preference in specific moment of activation per concept

	AR Concept			IC concept		
	Mean	**Min - Max**	**N**	**Mean**	**Min - Max**	**N**
Activation	6,55 ± 2,148	2 - 10	29	3,45 ± 2,148	0 - 8	29
Significate difference	Z = -3,111, p < 0,001					

Table 14 - Reasons about the preference by a concept in the specific moment of activation.

Points Distributed by concept		Transcription participants comments
IC	**AR**	
0	10	"Here, option IC, I wasn't safe that the car was in AD. I only knew because the physical response of the car. The IC didn't call my attention"
0	10	"I only looked to the IC past a long time in Option IC, I didn't look to the IC"
0	10	"Because in Option AR the information it's simpler"
1	9	"I prefer to see all in real, like in option AR. While I am looking to the road, appears what the AV is seeing and I love that"
1	9	"Because appears all the info in your field of view. I don't like to have duplicate information"
2	8	"In autonomous driving, I am seeing through the lines that the AV is driving well. The lines of IC help me too. The blue color I associated to the AD. Even though I trust in AD, it's never too much information. In IC, the car didn't move in the line, remain always in the center of the lane, however isn't true. In option AR the lines adapt to that. The car mark in AR option was very useful too"
2	8	"Because the information appears closer to the eyes (on road)"
2	8	"The lines projected above the real lines and the mark behind the car ahead increase a lot the confidence. In IC you have to stay all the time

Points Distributed by concept		Transcription participants comments
IC	AR	
		to check the information. I didn't miss the IC, but in the second lap I missed the AR screen."
2	8	"I prefer the option AR, however I want to remain with IC to see the information"
2	8	"The most important is the blue color and I think that I will detect faster in option AR that AD is activated"
2	8	"I saw more useful the option AR, but I would like to keep with option IC. I like and I saw useful the option IC too."
3	7	"It's clearer... It's more accessible the information... what help me was the text... but I would like to have the information repeat... the information not necessary all the time should appear in IC... in OA only should appears the main information to the moment... Without IC, you will put a lot of information in AR screen that maybe isn't necessary"
3	7	"The lines left me clearer that AD was activated"
4	6	"I prefer the option AR because the OA, for me in manual and autonomous mode shouldn't appears the lines"
4	6	"In autonomous driving, the information can appear in both displays, I prefer option AR, but for me both are ok, because in this moment I don't need attention"
4	6	"Because the lines that help you to know what the car was seeing but I saw useless don't appears nothing in IC"
4	6	"Because the most important is the change of color, so both options are ok. Maybe in option AR that change of color is noticed more."
4	6	"It's clearer the option AR and the option IC is more aesthetic. I will buy with both screens"
4	6	"Maybe it's more comfortable look to the IC than to the windshield, however during the video, sometimes I looked to the windshield."
4	6	"The info appears where I was looking"
4	6	"The information appears close of my eyes. What I hope of the IC it's show me information of the car. I will change the icon of TJ"
4	6	"Because the information appears already on the road. In this moment the lines didn't annoying, but for me are useless"
5	5	"I only focused in the color, so both are good."
5	5	"I distribute the same points imagining that option AR don't have lines. The car mark in option AR could remain there. I didn't see the icon in IC concept"
5	5	"Because in option IC I didn't see the visual info"
7	3	"Once was activated, it's not necessary information. However, I keep preferring option IC because the car info appears bigger"
7	3	"In option IC it's clearer because you have more space to apply design, so I saw more blue color in option IC. The blue lines here help me more (option AR), because gave me more information about autonomous driving"

Points Distributed by concept		Transcription participants comments
IC	AR	
7	3	"Because when I activate the AD, it's the same look for a screen or to the other."
8	2	"Because had info in road, so I don't like"

Acceptance

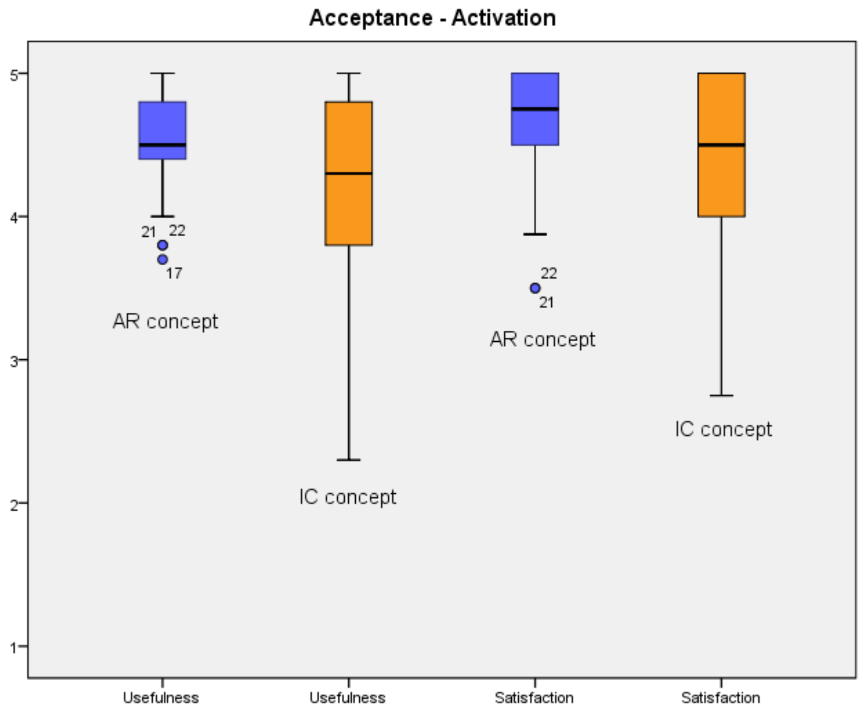
Reviewing data analysis showed that there were two participants in the "AR" concept, and one in the "IC" concept who mix the activation moment with other moment by comments. Since all participants should be awareness of this moment, we did not consider these two and one participants for the analysis. Finally, the used sample consisted of 27 participants in AR concept and 28 participants in IC concept.

Graphic 8 shows the boxplot of the points distributed by participants to the 9 items of Van der Laan questionnaire, already divided in usefulness and satisfaction according the concept tested, during activation moment. Table 15 shows all means, maximum, minimum and standard deviation of acceptance to the two concepts tested in the same moment.

In Graphic 8 we can to see that seems there is difference between the opinion about the usefulness between concepts, where is possible to see more negative variation in IC concept. On Table 15 we can see that the mean value of the usefulness opinion in both concepts is very positive, close to 4 points, in a scale the 1 until 5. The Wilcoxon analyses showed significant difference when comparing the opinion of usefulness between concepts ($Z= -2,862$, $p=0,001$) for an $\alpha=0,05$. So, it is to be admitted statistically that the participants consider more useful AR concept comparatively to IC concept in the specific moment of activation.

Relatively satisfaction variable, in Graphic 8 seems there is less difference than in usefulness variable, however it's visible the difference between concepts. In Table 15 we can to see that the IC concept has a minimum value under the AR concept, but both mean values are good (4,60 points to "AR concept" and 4,36 points to "IC concept"). The Wilcoxon analyses showed significant difference when comparing the opinion of satisfaction between concepts ($Est=-2,388$, $p=0,007$) for an $\alpha=0,05$. So, it is to be admitted statistically that the participants are more satisfied with AR concept comparatively to IC concept in the specific moment of activation.

During the questionnaire, when the participants didn't answer 'positively', the experimenter asked the participant what was the reason or what could to miss for be better. Table 16 shows these comments about "AR concept". We can highlight to the usefulness variable that the lines were the main topic, seen as positive and negative, about the satisfaction variable, we can highlight the lines again (Table 16). About the IC concept, we can see these comments on Table 17. We can highlight to the usefulness variable that some participants missed the "AR concept" and some participants mentioned that didn't see the icon, influencing negatively the driver responses (Table 17). About the satisfaction variable, the blue color was pointed by a participant as negative to associate to AD (Table 17).



Graphic 8 - Boxplot of acceptance variable by concept in the specific moment of activation

Table 15 - Distribution of the sample according with the usefulness and satisfaction during the activation moment

	AR Concept			IC Concept			Significate difference	
	Mean	**Min - Max**	**N**	**Mean**	**Min - Max**	**N**	**Est**	**p**
Usefulness	4,53 ± 0,41	3,7 – 5	27	4,18 ± 0,73	2,3 - 5,0	28	-2,862	0,001
Satisfaction	4,60 ± 0,44	3,5 – 5,0	27	4,36 ± 0,66	2,75 – 5,0	28	-2,388	0,007

Table 16 - Comments during the Van der Laan questionnaire when negative answers about the activation moment to "AR concept".

Usefulness	**Satisfaction**
Useful |__|__| X |__|__| Useless – "The lines in autonomous mode by a hand are useful because increase you trust (we can see what the car it's recognition), however it distracts me"	Pleasant |__ |__|__ | X |__| Unpleasant – "Lines no make me sense"
Assisting |__ |__ |__| X |__| Worthless - " It's enough the change of color, I already trust"	

Table 17 - Comments during the Van der Laan questionnaire when negative answers about the activation moment to "IC concept".

Usefulness	**Satisfaction**
Useful |__| X |__|__|__| Useless – "I miss the information in AR screen";	Pleasant |__|__| X |__|__| Unpleasant – "Because when change to blue color, put me more alert. Maybe orange is a better color to autonomous mode. I associated the orange to a relax color"
Useful |__|__|__|__|X| Useless – "There is too much info"	
Bad |__ |__ | X |__ |__| Good – "Should appears in HUD at least the AD icon"	
Effective |__| X|__ |__|__| Superfluous - "Seems more effective the other option. Here I only saw the change of color and I prefer the information on the road, in OA"	
Effective |__| X|__ |__|__| Superfluous – "Didn't give me information about my position in the lane"	

Awareness situation

Table 18 shows the responses for the 4 questions that we used to ensure the awareness situation during activation moment. The first question was how they knew that the AD function was activated and in "AR concept", what help the participants more were the change of color, follow by the message "AD activated" (pointed by 56,6% and 37%

respectively). In “IC concept”, what was more noticed to the participants to know that AD was activated was the blue color, followed by the change of color (mentioned by 46,4% and 42,9% of participants, respectively).

Then, we asked more specifically what the participant saw in this specific moment and to both concepts, the change of color was the visual information more seen (argued by >50% of participants in both concepts), followed by blue color that was seen by more than 45% of participants in both concepts. Other items were identified by few participants, as the car mark, lines and physical response of the car.

About the place where the participants saw the information, in “AR concept”, most of the participants (92,6%) identified the information appeared in AR area, place where appeared the lines and car mark, followed by the OA (pointed by 59,3% of the participants). In “IC concept”, most of participants (92,9%) identified the IC as the place where appeared the AD information and 1/3 of the participants saw the information in OA during this moment too.

The last question about this moment was how clear was to the participant understand that AD was activated and in both concepts, most the participants answer positively, however 93% of participants in “AR concept” gave the maxim punctuation, against 61% in “IC concept”. The Wilcoxon analyses showed significant difference when comparing the clarity to understand the information between concepts ($Z = -2,754$, $p = 0,002$) for an $\alpha=0,05$. So, it is to be admitted statistically that “AR concept” showed more clarity to understand by participants that AD was activated comparatively to “IC concept”.

In this last question, when the participants didn’t answer ‘very clear’, the experimenter asked to the participant what was the reason or what could to miss for be ‘very clear’. We can see on Table 19 these comments. We can highlight that to “IC concept” the negative comments were about the miss of some information beside the change of color in IC, as an icon, that the learning curve was bigger in “IC concept” comparatively to “AR concept” and that “IC concept” was less indicative. In “AR concept”, the negative comments were because the size of letters, the visibility of the icon and that miss some voice as “AD activated”.

Table 18 – Characterization of the sample according with the awareness situation on the specific moment of activation.

Activation of AD		AR concept		IC concept	
		N	%	N	%
How did you know that AD was activated?	Change of color	15	55,6%	12	42,9%
	Message AD activated	10	37,0%	7	25,0%
	Blue color	6	22,2%	13	46,4%
	Car mark	5	18,5%	3	10,7%
	Icon	5	18,5%	4	14,3%
	Sound	3	11,1%	4	14,3%
	Physical response of the car	2	7,4%	4	14,3%
	Change design	1	3,7%	1	3,6%
	Button	0	0,0%	1	3,6%
	Disappears advise AD Available	0	0,0%	1	3,6%
What did you see?	Change of color	18	66,7%	15	53,6%
	Blue color	16	59,3%	13	46,4%
	Car mark	14	51,9%	8	28,6%
	Lines	13	48,1%	1	3,6%
	Message AD activated	12	44,4%	11	39,3%
	Icon	6	22,2%	6	21,4%
	Physical response of the car	2	7,4%	2	7,1%
	Change design	1	3,7%	0	0,0%
	Video available	1	3,7%	0	0,0%
	Disappears fuel icon	0	0,0%	1	3,6%
	Disappears temperature icon	0	0,0%	1	3,6%
	Disappears message AD available	0	0,0%	1	3,6%
Where did you see the information?	AR area	25	92,6%	0	0,0%
	OA	16	59,3%	11	39,3%
	AR screen	14	51,9%	0	0,0%
	IC	0	0,0%	26	92,9%
How clear was for you to understand that AD was activated? *	1 (No clear)	0	0,0%	0	0,0%
	2	1	3,7%	2	7,1%
	3	0	0,0%	4	14,3%
	4	1	3,7%	5	17,9%
	5 (Very clear)	25	92,6%	17	60,7%
Significate difference	Z= -2, 754	P=0,002			

Table 19 – Participant comments about the clarify of activation moment.

AR Concept	IC concept
"I will putt the letters bigger and I will put the icon more visible (in the center)"	"I will add more cars to ADAS view, the button could show some color… no change the speed during all AD, no change 43…44…43…45…43…44.."
"The change of color isn't enough to know that AD was activated. I will add some voice like "AD activated"; "The HMI can be spoiled and change of color without stay in autonomous mode""	"Because in learning phase I didn't notice that AD was activated. Blue color isn't enough"
	"In the other was clearer, put 4 because the comparison…"
	"Miss an icon"
	"Less indicative, miss me something. The other option show me soon that everything worked well. The learning curve was bigger in this option. Since the first moment, the other option worked in intuitive way for me"
	"Less clear than before, now I had to search the info more than before, because didn't appears directly on windshield."

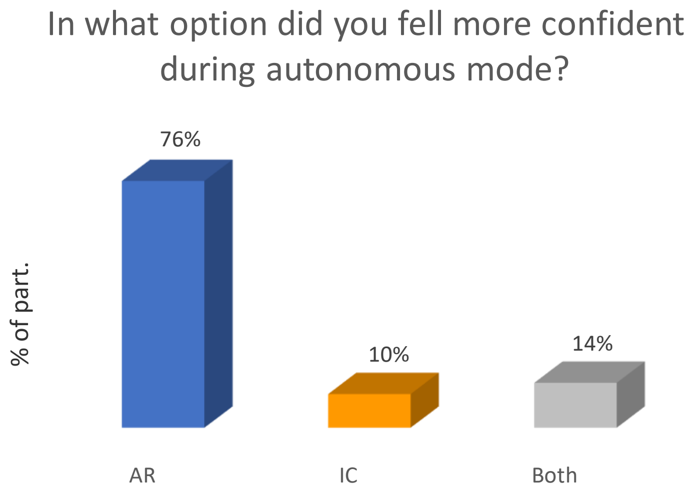
Confidence

Graphic 9 shows the display where the participants felt more confident during autonomous mode. Looking at the Graphic 9, more than 75% of the participants felt more confident in "AR concept" comparatively to "IC concept". 14% of the participants didn't feel difference in terms of confidence between concepts and only 10% of the participants felt more confident in IC concept.

We can see in Table 20 the reasons present by participants to feel more confident in a concept or in other. The main reasons presented by participants to feel more confident in "AR concept" were that the information didn't distract, the lines gave more perception of color, the info appeared closer of the driver eyes, see the same than the AV is seeing, showing that the car is working well, that the IC didn't call driver attention and that wasn't necessary force take the eyes of road to obtain information (Table 20).

The main reasons presented by participants to feel more confident in "IC concept" were that the IC was the place where the driver obtained information and that the IC was simpler (Table 20).

The main reasons presented by participants to didn't differentiate the confidence between concepts were because wasn't necessary driver attention in that moment, so the interface didn't influence the trust and what helped more in this moment was the change of color that was well visible in both concepts.



Graphic 9 – Percentage of participants according with the concept where they felt more confident during autonomous mode.

Table 20 – Participant comments about the reasons to feel more confident in AR concept, in IC concept or in both during autonomous mode.

AR Concept	IC concept	Both
"Because didn't distract me the information"	"When I was seeing the movie, I looked more to the IC than to the Road... When I looked to the road was to see the cars ahead and no for the information. I used the IC to obtain more information and I felt more comfortable."	"The important it's to check that our car is seeing the other cars. The lines didn't give me nothing"
" Because I could see more the colors in the lines and I mostly was looking to the road"	"I only looked to the speed in AR concept and the option IC was simple"	"What help me more was the change of color, no the distribution of information"
" Because I knew that the car was still good, without deviations. Our AC is seeing the car in front."		"Because I am not doing nothing"
"Because with lines a can see the vision of the car"		
"Because the information appears closer to the eyes (on road)"		
" Because I have more information to confirm that I am in autonomous mode... I only focused in HUD... and in option AR appeared more information there, so was easier for me to know. In option IC only changed the color"		
" I like to see what is happening with the car on road than look down to the IC"		
" The IC didn't call my attention"		
" Because I knew that the information will appears in windshield, so is more direct when I have to take control. "		
" Because the car mark give me the sensation that everything is working in a good way"		
" Because the information it's more accessible"		
" I had more present the info that the car gave me in each moment"		

AR Concept	IC concept	Both
” Because I like the lines and that the car maintains that distance”		
” In end of TJ, I knew easily that the car will ask me the control. I think that was because the car mark”		
” I had everything over the road. I didn't need to make an extrapolation like in option IC”		
” It does not force me to take my eyes off”		
” Seems that manage better the environment because show the information more realistic”		
” Because the lines, was intuitive that everything was ok”		
” Because I can keep with my eyes on road”		

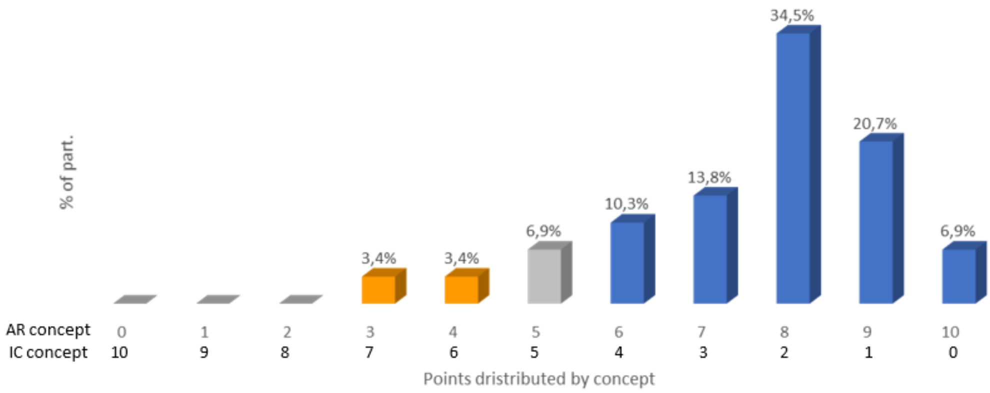
5.4.Give Back

During give back moment we evaluated the preference, acceptance, awareness situation, timing aspects and reaction types, comparing both concepts.

Preference

Graphic 10 shows the points distributed by participants in each concept according the preference of display during give back moment.

Looking at the Graphic 10, more than 85% of the participants (25/29) preferred the AR concept, 7% of the participants (2/29) didn't prefer none and only approximately 7% of the participants (2/29) preferred IC concept. Table 21 shows all the means, maximum and minimum of preference of two concepts tested. The mean value that the participants gave to "AR concept" was 7,48 points (SD = 1,703 points) and to "IC concept" was 2,52 points (SD = 1,703 points) (Table 21). The Wilcoxon analyses showed significant difference when comparing the preference between concepts ($Z = -4,349$, $p < 0,001$) for an $\alpha=0,05$. So, it is to be admitted statistically that the participants prefer "AR concept" in the specific moment of give back comparatively to "IC concept". We can see on Table 22 the reasons presented by participants after gave the points to each option. The participants with negative response to AR concept (<5 points preference to AR concept) gave like main reason that the information appears close of the eyes in the moment of see a movie in the central console (Table 22). The participants that didn't prefer any concept (=5 points preference to each concept) argued as main reason that an icon would be enough with the sound and that the design of IC is better than in AR screen, however in AR only miss a better contrast to be perfect (Table 22). The participants that preferred AR concept (>5 points preference to AR concept) argued as main reasons that after listen the sound, what they do first is look to the road, so they see first the information in AR concept, that the participants consider an important moment, so the information should appears on the road, that the information is very clear, that appears right where they were looking, that when you are alert, what you do first is look to the road, that if you look to the IC in this moment, you're losing information of road and some participants argued that didn't see visual information in IC (Table 22).



Graphic 10 - Percentage of participants according with the points distributed by concept about the preference about Give Back.

Table 21 - Descriptive statistics about the preference in specific moment of Give Back per concept

	AR Concept			IC concept		
	Mean	**Min - Max**	**N**	**Mean**	**Min - Max**	**N**
Activation	7,48 ± 1,703	3 - 10	29	2,52 ± 1,703	0 - 7	29
Significate difference	Z = -4,349, p < 0,001					

Table 22 - Reasons about the preference by a concept in the specific moment of Give Back.

Points Distributed by concept		**Transcription participants comments**
IC	**AR**	
0	10	"I didn't see this in IC. I only saw the text, I didn't see the icons"
0	10	"It's an important moment and it's good appears on the road"
1	9	"Because in option IC only listen the sound, seems an error not appears nothing in HUD about this moment... because when I listen the sound, what I do first is look to the road to know what happened... in option AR you had the information there and it's very clear"
1	9	"Without doubts, because you are always looking to the windshield to check that everything was ok, so appears the information there is more adequate"
1	9	"Call more my attention, appears in the eyes way the change to red color"
1	9	"Because in option AR you can see faster the information and didn't distract so much. I gave 1 point to Option IC because is equal in effectiveness"
1	9	"Sound --> Road --> IC, so I saw first the information in option AR, but I saw useful the option IC too"
1	9	"Was much more effective because appears where I was looking"
2	8	"Because is closer to the eyes. Option AR was clearer"

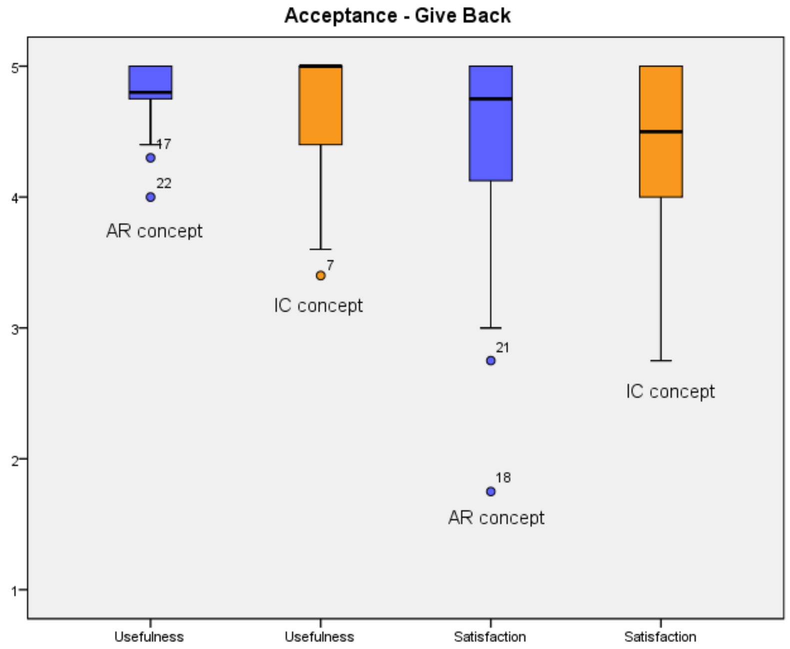
Points Distributed by concept		Transcription participants comments
IC	**AR**	
2	8	"Easier, more accessible. If you must look to the IC, you are losing information of road"
2	8	"When I listen the sound, my eyes call me to look to the road"
2	8	"When you are alert, what you look first is the road"
2	8	"I prefer keep with my eyes on the road, so seems genial to see the message in that position, was ok (option AR). I gave 2 points to option IC because was ok the message in that size in IC. Maybe I will change the red color to orange or other color less intrusive..."
2	8	"Because I saw clearer in option AR"
2	8	"When I listen the sound, my eyes call me to look to the road"
2	8	"I prefer receive in both screens, but if I had to choose one, I will choose the option AR"
2	8	"Seems an essential moment, so the information should appear in windshield"
2	8	"When I was seeing the movie, I listen the sound, look to the road and after to IC, so I saw first the alert in AR option, it's right where you are looking"
3	7	"In the second option appears in sight. Appeared in front of my eyes and in a big size"
3	7	"Because after you listen the sound, you look to the road. The symbols are clear in both options"
3	7	"I am not always seeing the IC, but I am always seeing the road, so I will see earlier the message in AR option"
3	7	"First sound, after I look to the road, so it's easier to read the message in AR option"
4	6	"The image is bigger. When you listen the sound, you look automatically to the road so the information appears there it's ok. The option IC it's ok too, because when I was distracted seeing the movie, I looked to the IC. It would be ok there is both options"
4	6	"Allow me keep the attention and seems easier"
4	6	"For me in this moment what call more my attention is the sound, so the visual information is less important. If I am distracted, after I listen the sound, I look to the road because I already know what I should to do"
5	5	"The icon should be enough with the sound"
5	5	"In option IC, the design (contrast) is better, I didn't see the icon in option AR because there is few difference of contrast. If the design of option AR was better, I will prefer the option AR, but in this moment, I prefer option IC"
6	4	"Because the message appears close of the eyes, so it's easier to see the information"
7	3	"When I was seeing the movie, my eyes were closer the IC than the windshield, so I saw better the option IC. Maybe the messages could be repeated, but fundamental is appears in IC"

Acceptance

Reviewing data analysis showed that there were two participants in the "IC" concept who mix the give back moment with other moment by comments. Since all participants should be awareness of this moment, we did not consider these two participants for the analysis. Finally, the used sample consisted of 29 participants in AR concept and 27 participants in IC concept.

Graphic 11 shows the boxplot of the points distributed by participants to the 9 items of Van der Laan questionnaire, already divided in usefulness and satisfaction according the concept tested, during give back moment. Table 23 shows all means, maximum, minimum and standard deviation of acceptance to the two concepts tested in the same moment.

In Graphic 11 we can to see that seems there isn't difference between the opinion about the usefulness between concepts, however seems there is less variation in AR concept. On Table 23 we can see that the mean value of the usefulness opinion in both concepts is very positive, close to 4,5 points, in a scale the 1 until 5. The Wilcoxon analyses showed no significant difference when comparing the opinion of usefulness between concepts (Z= -1,648, p=0,051) for an α=0,05. Relatively satisfaction variable, in Graphic 11 seems there isn't difference between concepts. In Table 23 we can to see that the AR concept has a minimum value under the IC concept, but both mean values are good (4,40 and 4,32 respectively). The Wilcoxon analyses showed no significant difference when comparing the opinion of satisfaction between concepts (Est=-0,468, p=0,329) for an α=0,05. During the questionnaire, when the participants didn't answer 'positively', the experimenter asked the participant what was the reason or what could to miss for be better. We can see on Table 24 the comments about the AR concept. We can highlight to the usefulness that the participants would like to receive the GB earlier and appears the icon of time could improve the awareness situation by a side and by other side increase the pression (Table 24). About the satisfaction variable, we can highlight that the participants maybe prefer only visual information first and if the driver don't take control, appears the sound as a complementary (Table 24). About the "IC concept", we can see the comments on Table 25. We can highlight to the usefulness that the message appears to late in end of traffic jam situation and the red color was too alert (Table 25). About the satisfaction variable, appears first only visual information was pointed as to AR concept (Table 25).



Graphic 11 - Boxplot of acceptance variable by concept in the specific moment of Give Back

Table 23 - Distribution of the sample according with the usefulness and satisfaction in the Give Back moment

	AR Concept			**IC Concept**			**Significate difference**	
	Mean	**Min - Max**	**N**	**Mean**	**Min - Max**	**N**	**Est**	**p**
Usefulness	4,81 ± 0,25	4,0 – 5	29	4,66 ± 0,50	3,4 - 5,0	27	-1,648	0,051
Satisfaction	4,40 ± 0,87	1,75 – 5,0	29	4,32 ± 0,73	2,75 – 5,0	27	-0,468	0,329

Table 24 - Comments during the Van der Laan questionnaire when negative answers about the Give Back moment to AR concept.

Usefulness	Satisfaction
Useful |__|__| X |__|__| Useless – "Because the message appears to late. I had taken control before the car ask me"	Nice |__ |__| X |__|__| Annoying – "In my opinion first should appears only visual, during 2 seconds, and after should appears the sound like is in this moment"
Bad |__ |__ |__| X |__| Good - "Seems good without time. Time=pressure"	Undesirable |__ |__| X |__|__| Desirable – "Alert and annoying, but it's ok"
Bad |__ | X |__|__|__| Good – "Miss the time"	
Irritating |__|__| X |__|__| Likeable – "Because the red color alert me a bit"	
Raising Alertness |__| X |__|__|__| Sleep Inducing – "Soft, it's ok. I didn't feel the sensation of "WHATTT?"	

Table 25 - Comments during the Van der Laan questionnaire when negative answers about the Give Back moment to IC concept.

Usefulness	Satisfaction
Useful |__|__| X |__|__| Useless – "It's useful, but I will take control before… call me too late";	Irritating |__|__| X |__|__| Likeable – "Red color scares me"
Useful |__|__| X |__|__| Useless – "I don't see much the detail. I will prefer a GIF to understand better. Be careful with the sound"	
Effective |__| X|__ |__|__| Superfluous - " Because the comparison"	
Effective |__|__|__| X |__| Superfluous – "I in other option saw the info before"	
Assisting |__|X|__|__|__| Worthless - "Because message appeared to late"	
Assisting |__|X|__|__|__| Worthless – "Don't give the time"	

Awareness situation

Table 26 shows the responses for the 4 questions that we used to ensure the awareness situation during Give Back moment. The first question was how they knew that the car was asking the control and in both concepts, what helped the participants more was the sound (noticed by 69% in “AR concept“ and 89% in IC concept). In visual terms, what helped more in AR concept was the red color (pointed by 76% of the participants), followed by the message “Take control” (pointed by 59% of participants). In IC, in visual terms, what helped more was the message “Take control” (pointed 64% of participants), followed by the red color and icon of SW (pointed by 46% of participants each one).

Other visual aspects were identified in both concepts as the change of color, icon of pedal, hand, foot and brake pedal (pointed by less than ¼ of participants).

About the place where the participants saw the information, to the “AR concept“, most of the participants (76%) identified the information appeared in AR area, place where appeared really the message, followed by the OA, pointed by 48% of the participants. In “IC concept“, most of participants (93%) identified the IC as the place where appeared the AD information and 4 participants (14%) saw wrongly the information in OA during this moment too.

The last question about this moment was how clear was to the participant understand that AD was activated and in both concepts, most the participants answer positively. All the participants in “AR concept“ gave the maxim punctuation about the clarity of understand the information and in IC, 89% gave the maximal punctuation too. The Wilcoxon analyses showed no significant difference when comparing the clarity to understand the information between concepts ($Z = -1{,}732$, $p = 0{,}125$) for an $\alpha = 0{,}05$.

As the results above presented showed, the results were very positives about this topic to both concepts, so no comments to improve were pointed by participants about the clarity of the information during GB.

Table 26 – Characterization of the sample according with the awareness situation on the specific moment of Give Back.

Give Back of AD		AR concept		IC concept	
		N	%	N	%
How did you know that the car was asking you the control?	Sound	20	69,0%	24	85,7%
	Red color	19	65,5%	10	35,7%
	Message "Take Control"	12	41,4%	14	50,0%
	Change of color	6	20,7%	4	14,3%
	Icon of SW	6	20,7%	10	35,7%
	Icon of pedal	4	13,8%	5	21,4%
	Icon of hand	3	10,3%	4	14,3%
	Icon of foot	1	3,4%	3	10,7%
	Icon brake pedal	1	3,4%	1	3,6%
	Orange lines	1	3,4%	0	0,0%
	Icon of accelerator	1	3,4%	1	3,6%
	Red letters	0	0,0%	0	0,0%
	Yellow color	0	0,0%	1	3,6%
	Flicker in red	1	3,4%	1	3,6%
	Vibration in SW	1	3,4%	2	7,1%
What did you see?	Red color	22	75,9%	13	46,4%
	Message "Take Control"	17	58,6%	18	64,3%
	Icon of SW	9	31,0%	13	46,4%
	Icon of pedal	7	24,1%	9	32,1%
	Change of color	5	17,2%	5	17,9%
	Icon of hands	3	10,3%	4	14,3%
	Icon of foot	1	3,4%	4	14,3%
	Orange color	0	0,0%	3	10,7%
	Icon brake pedal	1	3,4%	2	7,1%
	Orange lines	1	3,4%	0	0,0%
	Icon of accelerator	1	3,4%	1	3,6%
	Nothing	1	3,4%	1	3,6%
	Change of design	1	3,4%	0	0,0%
	End of TJ	1	3,4%	0	0,0%
	Flicker in red	2	6,9%	1	3,6%
	Stop video	2	6,9%	0	0,0%

Give Back of AD		AR concept		IC concept	
		N	%	N	%
Where did you see the information?	AR area	22	75,9%	0	0,0%
	OA	14	48,3%	4	14,3%
	AR screen	8	27,6%	0	0,0%
	Nothing	1	3,4%	1	3,6%
	IC	0	0,0%	26	92,9%
	IC + HUD	0	0,0%	4	10,7%
How clear was for you to understand that the car was asking you the control?	1 (No clear)	0	0,0%	0	0,0%
	2	0	0,0%	0	0,0%
	3	0	0,0%	0	0,0%
	4	0	0,0%	3	10,7%
	5 (Very clear)	28	100%	25	89,3%
Significate difference	Z=- 1,732	P=0,125			

Timing aspects

Reviewing quantitative data analysis showed that there were six participants in the “AR concept”, and eight in the “IC concept” who technical problems didn’t get the results well. So, we did not consider these six and eight participants for the analysis. Finally, the used sample consisted of 23 participants in AR concept and 21 participants in IC concept.

Table 27 shows all means, maximum, minimum and standard deviation of reaction times to “Hands on”, of two concepts tested and the possible influence of secondary task. Looking at the hands-on data in general, no considering if the participants were doing the ST, the difference of the “hands on reaction” seems negligible small, since the means are between 1,94 (“AR concept”) and 2,00 (“IC concept”) (Table 27). Since the data was not normally distributed we applied a Wilcoxon test, which revealed no significant difference (Z= -0,469, p=.329) (Table 27). When just before the GB the participants were seeing the movie, the “Hands on reaction time” was better in “AR concept” (M= 2,08s; SD=0,63s), comparatively to “IC concept” (M=2,28s; SD=1,01s) (Table 27) (Table 27). The Wilcoxon analyses showed no significant difference when comparing the “Hands on reaction time” when the participants were distracted with secondary task between concepts (Z = -0,574, p = 0,290) for an α=0,05 (Table 27). When just before the GB the participants were free to look to the road, the “Hands on reaction time” was better in “IC concept” (M=1,73 s; SD=0,81s) comparatively to “AR concept” (M=1,80s; SD=0,67s) (Table 27). The Wilcoxon analyses showed no significant difference when comparing the “Hands on reaction time” when the participants were no distracted between concepts (Z

= -0,469, p = 0,329) for an α=0,05 (Table 27). The time of "Hands on" was significate worst in both concepts when the driver was doing the secondary task just before the GB comparatively when the participants were free to look to the road (Z=-2,972; p<0,001 when we compared "IC concept" with and without ST and Z= -1,737; p=0,042 when we compared "AR concept" with and without ST).

Table 27 - Distribution of the sample according with the reaction time of "Hand on" during the Give Back moment

	AR Concept			IC Concept			Significate difference	
	Mean	**Min - Max**	**N**	**Mean**	**Min - Max**	**N**	**Est**	**P**
General	1,94 ± 0,54	1,15 - 3,58	23	2,00 ± 0,67	1,06 - 3,31	21	-0,469	0,329
With ST	2,08 ± 0,63	1,18 - 3,93	23	2,28 ± 1,01	1,11 - 4,75	21	-0,574	0,290
Without ST	1,80 ± 0,67	0,80 - 3,83	23	1,73 ± 0,81	0,89 - 4,90	21	-0,469	0,329

Table 28 shows all means, maximum, minimum and standard deviation of reaction times to "take control", of two concepts tested and the possible influence of secondary task. Looking at the "take control time" data in general, no taking into a count if the participants were doing the ST, the difference of the "take control reaction" seems negligible small, since the means are between 2,38s ("AR concept") and 2,44s ("IC concept"). Since the data was not normally distributed we applied a Wilcoxon test, which revealed no significant difference (Z=-0,608, p=0.281). When just before the GB the participants were seeing the movie, the "take control reaction time" was better in "AR concept" (M= 2,61s; SD=0,95s), comparatively to "IC concept" (M=2,85s; SD=1,17s) (Table 28). The Wilcoxon analyses showed no significant difference when comparing the "take control reaction time" when the participants were distracted with secondary task between concepts (Z = -1,234, p = 0,114) for an α=0,05. When just before the GB the participants were free to look to the road, the "take control reaction time" was better in "IC concept" (M=2,02s; SD=0,86s) comparatively to "AR concept" (M=2,13s; SD=0,80s). The Wilcoxon analyses showed no significant difference when comparing the "take control reaction time" when the participants were no distracted between concepts (Z = -0,469, p = 0,329) for an α=0,05. The time of "Take control" was significate worst in both concepts when the driver was doing the secondary task just before the GB comparatively when the participants were free to look to the road (Z=-2,485; p=0,006 when we compared IC with and without ST and Z= -2,585; p=0,004 when we compared AR with and without ST).

Table 28 - Distribution of the sample according with the reaction time of "take control" during the Give Back moment

	AR Concept			IC Concept			Significate difference	
	Mean	**Min - Max**	**N**	**Mean**	**Min - Max**	**N**	**Est**	**P**
General	2,38 ± 0,79	1,42 - 4,39	23	2,44 ± 0,71	1,22 - 3,64	21	-0,608	0,281
With ST	2,61 ± 0,95	1,34 - 4,89	23	2,85 ± 1,17	1,11 - 5,13	21	-1,234	0,114
Without ST	2,13 ± 0,80	0,80 - 4,14	23	2,02 ± 0,86	1,02 - 4,90	21	-0,521	0,308

Reaction types

The subjects can be distinguished by their reaction. Therefore, the subjects were divided into two groups. In both concepts, most of participants "take control" by "steer and accelerator", during an end of traffic jam. Only a participant "brake and steer" in both concepts too.

5.5. Deactivation

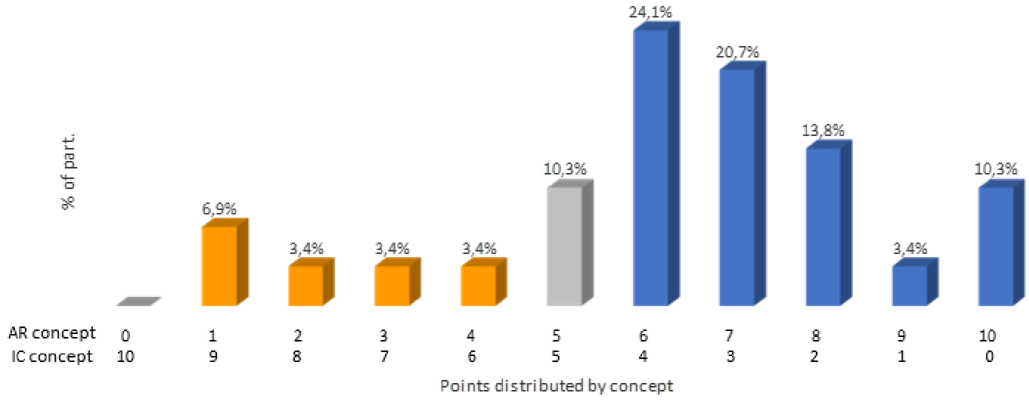
During deactivation moment, we evaluated the preference and awareness situation, comparing both concepts.

Preference

Graphic 12 shows the points distributed by participants in each concept according the preference of display during deactivation moment.

Looking at the Graphic 12, more than 70% of the participants (21/29) preferred the AR concept, 10% of the participants (3/29) didn't prefer anyone and approximately 17% of the participants (5/29) preferred IC concept. The mean value that the participants gave to "AR concept" was 6,24 points (SD = 2,385 points) and to "IC concept" was 3,76 points (SD = 2,385 points) (Table 29). The Wilcoxon analyses showed significant difference when comparing the preference between concepts ($Z = -2{,}480$, $p = 0{,}006$) for an $\alpha=0{,}05$. So, it is to be admitted statistically that the participants prefer "AR concept" in the specific moment of deactivation comparatively to "IC concept". We can see on Table 30 the reasons presented by participants after gave the points to each option. The participants with negative response to AR concept (<5 points preference to AR concept) gave like main reason that they had more yellow color in IC option, that they are get used to receive information in IC, that the text in OA was too small and that the lines were invasive (Table 30). The participants that didn't prefer any concept (=5 points preference to each concept) argued as main reason that the most important was the color, that the text wasn't important in this moment, that the AR option was more effective, however the IC had better design (Table 30).

The participants that preferred AR concept (>5 points preference to AR concept) argued as main reasons that they didn't see the text in IC option, only in AR concept, that the information was more accessible, clean and direct in AR concept, that it's possible see more color and because the information appeared in the field of view of the drivers (Table 30).



Graphic 12 - Percentage of participants according with the points distributed by concept about the preference about the Deactivation.

Table 29 - Descriptive statistics about the preference in specific moment of Give Back per concept

	AR Concept			IC concept		
	Mean	**Min - Max**	**N**	**Mean**	**Min - Max**	**N**
Activation	6,24 ± 2,385	1 - 10	29	3,76 ± 2,385	0 - 9	29
Significate difference	Z = -2,480, p = 0,006					

Table 30 - Reasons about the preference by a concept in the specific moment of Deactivation.

Points Distributed by concept		**Transcription participants comments**
IC	**AR**	
0	10	"I didn't see this in IC"
0	10	"I will increase the size of letter"
0	10	"Because is where I saw the information"
1	9	"During the test, I never look to the IC."
2	8	"Easier and more accessible"
2	8	-
2	8	"Because seems better have everything in only 1 display. It bothers me to go down with my eyes to manage the speed and in AR option you have everything in your field of view"
2	8	"Because in AR option I saw the information, in IC option I didn't see the information"
3	7	"Because the information is clean and direct... but I remain to use the IC to show information, but seems adequate appears on the road in my angle of vision"
3	7	"I like more the text in OA, but I remain to like to have information in IC"

Points Distributed by concept		Transcription participants comments
IC	AR	
3	7	"I didn't see the message in IC option. In IC option, what help me was the physical response of the car. At least in AR option I could saw the text better. I liked a lot."
3	7	"Because I can see the information better represented in windshield"
3	7	-
3	7	"Color is what help you more and it's more difficult to see the text in IC option than in AR option, because the info is clean. I only put 7 points in option 2 imagining that the lines weren't there"
4	6	"Because when I was driving I looked to the road, however you didn't need so much information"
4	6	"I like the information in AR option"
4	6	"The information appeared closer to the eyes. I will buy the car with IC and AR"
4	6	"The important was the color. The text I almost can't read. I prefer option AR because you didn't distract your attention"
4	6	"The information appeared closer of my eyes. I hope a green color to manual mode, not yellow"
4	6	"Because it's the place where I was looking"
4	6	"Because appeared in my field of view"
5	5	"The most important was the color. The message didn't give me nothing in this moment"
5	5	-
5	5	"The AR option was more effective, however the IC option had a better design. If I must have bought a car, I will buy the AR option because I am more get used to it."
6	4	"You have more yellow color, call me more attention that the phrase and sound"
7	3	"It's clearer for me"
8	2	"Because I am not get used to receive info in windshield"
9	1	"The text in AR option was too small and I didn't see"
9	1	"Lines to invasive"

Awareness situation

Table 31 shows the responses for the 4 questions that we used to ensure the awareness situation during deactivation moment. The first question was how they knew that AD was deactivated and in both concepts, what helped the participants more was the change of color (noticed by 59% in AR concept and 54% in IC concept), followed by physical response of the car (pointed by 45% and 39% respectively by concept). In visual terms, the change of color was the main characteristic identified by participants in both concept (pointed by 62% and 57% of the participants respectively). We can see on the Table 31 other visual aspects identified in both concepts as the lines, orange color, message “AD deactivated”, disappearing the icon and disappearing time gap (pointed by less than ¼ of participants).

About the place where the participants saw the information, to the AR concept, most of the participants (76%) identified the information appeared in AR screen, followed by the OA, pointed by 52% of the participants and AR area pointed by 35% of participants. In IC concept, most of participants (86%) identified the IC as the place where appeared the AD information and 13 participants (46%) noticed this moment through the OA.

The last question about this moment was how clear was to the participant understand that AD was deactivated and in both concepts, most the participants answer positively. 86% of the participants in AR concept gave the maxim punctuation about the clarity of understand the information and in IC, 75% gave the maximal punctuation too Table 31. The Wilcoxon analyses showed no significant difference when comparing the clarity to understand the information between concepts ($Z = -0,904$, $p = 0,227$) for an $\alpha=0,05$.

In this last question, when the participants didn’t answer ‘very clear’, the experimenter asked to the participant what was the reason or what could to miss for be ‘very clear’. We can see on Table 32 those comments. We can highlight that to “IC concept” the negative comments were that miss some icon, the text should stay more time, the size of the text should be bigger and miss some sound. In “AR concept“, the negative comments were because the quantity of information about the deactivation and that miss some sound.

Table 31 – Characterization of the sample according with the awareness situation on the specific moment of Deactivation.

Deactivation of AD		AR concept		IC concept	
		N	%	N	%
How did you know that AD was deactivated?	Change of color	17	58,6%	15	53,6%
	Physical response of the car	13	44,8%	11	39,3%
	Orange color	6	20,7%	6	21,4%
	Lines	4	13,8%	0	0,0%
	Yellow color	4	13,8%	1	3,6%
	Message AD Deactivated	3	10,3%	4	14,3%
	Disappears AD icon	3	10,3%	0	0,0%
	Sound	3	10,3%	4	14,3%
	Deactivation of video	2	6,9%	0	0,0%
	Low speed	1	3,4%	0	0,0%
	Disappears GB message	1	3,4%	2	7,1%
	Disappears car mark	1	3,4%	2	7,1%
What did you see?	Change of color	18	62,1%	16	57,1%
	Lines	8	27,6%	0	0,0%
	Orange color	5	17,2%	6	21,4%
	Yellow color	5	17,2%	2	7,1%
	Disappears AD icon	5	17,2%	1	3,6%
	Message AD Deactivated	4	13,8%	4	14,3%
	Deactivation of video	4	13,8%	1	3,6%
	Disappears car mark	4	13,8%	4	14,3%
	Disappears GB message	3	10,3%	2	7,1%
	Low speed	1	3,4%	0	0,0%
	Disappears blinking	1	3,4%	0	0,0%
	Speed in orange	0	0,0%	1	3,6%
	Appears temperature	0	0,0%	1	3,6%
	Appears fuel	0	0,0%	1	3,6%
	Nothing	0	0,0%	1	3,6%
	Change design	0	0,0%		7,1%
	Word "Manual"	0	0,0%	1	3,6%
	Some text	0	0,0%	1	3,6%

Deactivation of AD		AR concept		IC concept	
		N	%	N	%
Where did you see the information?	AR Screen	22	75,9%	0	0,0%
	OA	15	51,7%	13	46,4%
	AR Area	10	34,5%	0	0,0%
	AR Screen + CC	1	3,4%	0	0,0%
	IC	1	3,4%	24	85,7%
	Nowhere	0	0,0%	2	7,1%
	IC + HUD	0	0,0%	11	39,3%
How clear was for you to understand that the car was asking you the control?	1 (No clear)	1	3,4%	0	0,0%
	2	0	0,0%	1	3,6%
	3	0	0,0%	0	0,0%
	4	2	6,9%	6	21,4%
	5 (Very clear)	25	86,2%	21	75,0%
Significate difference	Z= -0,904	P=0,227			

Table 32 – Participant comments about the clarify of deactivation moment.

AR Concept	IC concept
"Miss some sound"	"Miss me some icon. I didn't see nothing"
"I need more information to know that AD was deactivated. I wasn't safe that AD was deactivated"	"In OA I saw better the icon than in IC"
	"The phrase should stay more time and the size should be bigger. More exposition of the phrase. Miss some feedback permanent. In general, should there is an icon of AD like appears to the lights when activate…"
	"Should to have sound"

5.6. Rear end collision

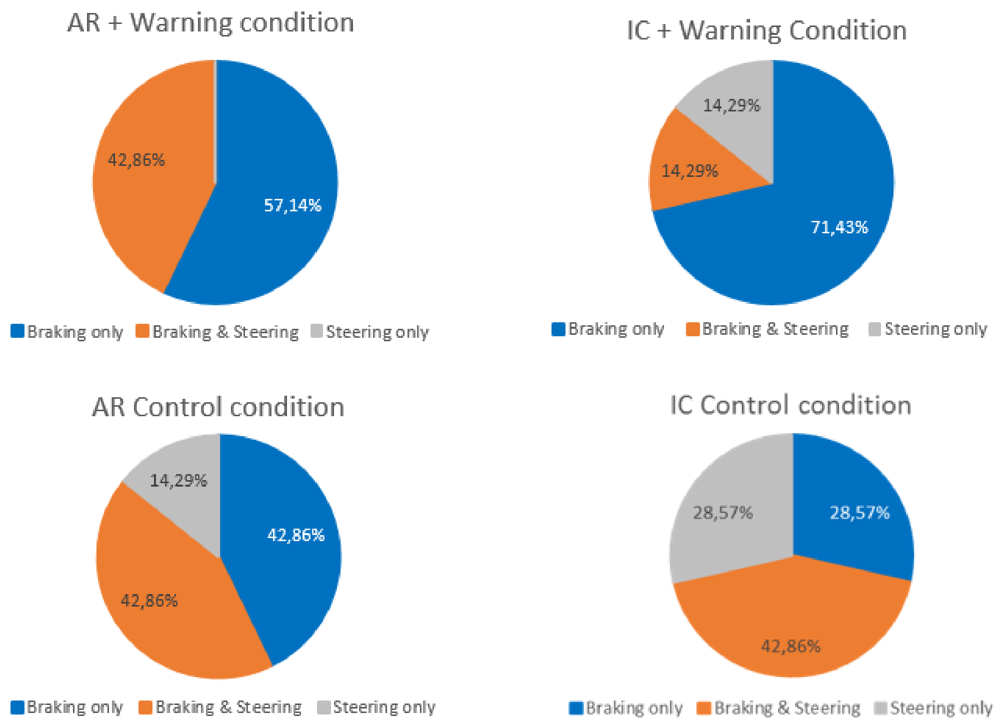
During rear end collision moment, we evaluated the types and times of reaction. As in this collision avoidance emergency, we considered four types of reaction where a hierarchy was established in terms of behaviors safety. We consider the safest behavior braking and at the same time turning the steering wheel. The second safest was braking only. The third was turn the steering wheel only. We compared four groups (G1 – "AR + warning condition"; G2 – "IC + warning condition"; G3 – "AR control condition without warning"; G4 – "IC control condition without warning").

For technical reasons with quantitative data collection one of the participants was eliminated from sample. Thus, the used sample consisted of 28 participants, 7 in "AR concept" with warning, 7 in "IC concept" with warning, 7 in "AR concept" control condition and 7 in "IC concept" control condition.

Reaction types

Graphic 13 shows the reaction types in each group during rear end collision.

Looking at the Graphic 13, the participants that received warning in "AR concept" showed a safer behavior with a higher percentage of drivers braking and steering (42,86%) against only 14,29% in the "IC concept" with warning. In the control conditions the percentage of safer behaviors (braking and steering) were equal, however the "IC concept" control condition was more penalized because the percentage of less safe behaviors (turning the wheel) was 28,57% against 14,9% in "AR concept" control condition (Graphic 13).

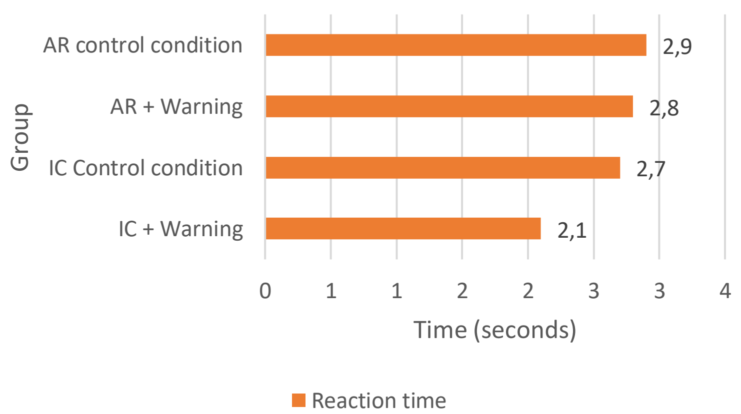


Graphic 13 – Types of reaction during rear end collision by group.

Reaction times

Graphic 14 shows the reaction times (Time since the obstacle is visible until the driver move the "Steering Wheel angle >2º" or make a "difference brake pressure > 10).

Looking at the reaction time, the "IC concept" with warning (M= 2,1s) showed better results comparatively to "AR option" with warning (M= 2,8s), as well as in "IC concept" control condition (M= 2,7s) and "AR concept" control condition (M= 2,9s) (Graphic 14).



Graphic 14 – Reaction time (Since appears the warning until the driver: "Steering Wheel angle >2º" or "difference brake pressure > 10%") by group

6. Discussion

Intermediate levels in which the human is expected to monitor the automated driving system, may be particularly hazardous because humans are unable to remain vigilant for prolonged periods of time (Casner et al., 2016; D. A. Norman, 2015). In short, the driver during AD level 3 (SAE,2016) is out of loop in some moments. The objective of the current study was to investigate drivers' interactions with a novelty AR display and compare with the current displays in the market during manual mode and autonomous driving level 3 (SAE, 2016) and the transitions between modes.

We were particularly interested in the driver user experience, acceptance, awareness situation and confidence to the displays tested. To answer these research questions self-report and specific software methodologies were used.

In manual mode, we evaluated the driver preference and the confidence. In terms of preference, the results showed significate difference between concepts, so we can assume that the user experience was clearly better in "AR concept" (21/29 participants). This findings are according Park and Park (2019) expectations. The main reasons presented by these participants were that the information in Operational Area (OA) was very accessible, that distracted less than the information in Instrument Cluster (IC) and that appeared right in their field of view. Most of these participants didn't distributed the totally of points to "AR concept" (10 Points to "AR concept" and 0 points to "IC concept") because the lines that appeared in AR area, that was like a "videogame" and that distracted. From a computer graphics perspective, the lines accuracy wasn't evaluated by users, however we think that could explain the fact of most of participants didn't give the maximum points to "AR concept". Those lines had a delay between the user action in the SW and the real visual information displayed in windshield, so seemed that the driver was all the time adjusting his position in the lane. The participants that preferred "IC concept" (6/29) argued as main reasons the fact of habit with receiving information in IC and the lines that appeared in AR screen. This habit could be exceeded by experience with windshield display, once that the participants after used AR information during the test, commented that didn't miss the IC and that was fast the learning phase with it.

In terms of confidence, the results showed a trend to "AR concept" again. The main reasons presented by the participants that felt more confidence in "AR concept" during manual mode were the localization of information that was very accessible to the driver, that the IC that they are get use nowadays is useless and that distract less get the information there (AR screen). These results can be explained in fact of the driver with “AR concept” didn’t need take his eyes of the road to get car information, by other side, in “IC concept” only the current speed and speed limit appeared on the road. The IC using nowadays in car is negative in terms of safety, once that the driver, all the times that try get information from there, is distracted of the main task. In this test, no quantitative data was obtained to evaluate both concepts, however no rarely behaviors were observed.

In availability moment, we evaluated the driver preference, acceptance and awareness situation. In terms of preference, the results showed significate difference between concepts, so we can assume that the user experience was clearly better in “AR concept” (24/29 participants). This findings are according Park and Park (2019) expectations, where they argued that the HUD systems have a potential to improve the driver experience. The main reasons presented by these participants were that seen the visual information faster, in the field of view and some participants said that the information was easy to see. These results can be explained by the fact of the information in “AR concept” appeared in windshield and that the information in AR screen was “cleaner”, comparatively to “IC concept” that appeared in IC and was more complicated found the information in the middle of the quantity of information. This moment for some participants it’s very fast, because press the AD button to activate the AD during the first seconds of AD available, so the visual information can be no seen. The participants that preferred the “IC concept” (3/29) argued as main reason the size of information in OA too small and the lines in AR screen as negative. The participants that preferred “IC concept” was because negative points identified in “AR concept” and no try found positive points about “IC concept”. These results can give stronger to “AR concept”, once that an improving of design could increase the user experience of these participants.

In terms of acceptance, the questionnaire used (Van Der Laan questionnaire) divide this variable in two other variables, usefulness and satisfaction. In terms of usefulness, the results showed significate difference between concepts, so we can assume that the “AR concept” is more useful comparatively to “IC concept”. The main reasons presented by these participants were that didn’t see the visual information (text and icon) in “IC concept”. As in this moment the driver is the responsible by the car safety, his eyes should stay on the road whereby “AR concept” was according with eyes behavior, once that displayed the information on the road and the driver didn't need change the eyes of road as did in "IC concept". In terms of satisfaction, the results showed no significate difference. These results can be explained by the fact of during the test the only sound used was about the AD, so the participants in this moment maybe listen the sound and quickly understood that AD was available, so was equal of effective. In both concept the difference was only visual, so the sound can explain the fact of no significate difference in the participant's satisfaction.

In terms of awareness situation, the results showed statistical significate difference between concepts. It's admitted that the participants were more awareness in "AR concept" comparatively to "IC concept" because they found the information clearer to understand. The sound was the main help in both concepts, followed by the message "AD available". The icon was noticed by less than 1/5 of participants in both concepts. These results can be explained by the fact of there was no sound that could mix with AD sound, so the participants by the learning phase already knew that when they were in Manual mode and heard the sound, it's because that AD was available. The message "AD available" was more noticed comparatively to the icon, maybe because the position. The design of the AD icon was pointed as negative by most of the participants, that seemed an airplane, and that could influence negatively the awareness situation. Two participants in "IC concept" assumed that didn't see anything. The learning phase to adaptation to autonomous driving was short and for that some details of HMI was ignored or not perceived, mainly the AD icon and that can explain the thought of "lack of information" by some participants. A re design of the AD icon should be considered.

In activation moment, we evaluated the driver preference, acceptance and awareness situation. In terms of preference, the results showed significant difference between concepts, so we can assume that the user experience was clearly better in "AR concept" (22/29 participants). This findings are according Park and Park (2019) expectations, where they argued that the HUD systems have a potential to improve the driver experience. The main reasons presented by these participants were that the user could see the same information that the autonomous vehicle (lines detection and distance car ahead), that the information appeared in the field of view of driver and that it's more accessible. These results can be explained by the fact of the sample tested had low levels of confidence to autonomous driving, because is a new technology under development, so appears the information on the road, adapting to the real conditions, had a positive impact in the user experience. The participants that preferred “IC concept” was because in IC could see the car information bigger, the most important was the change to blue color, that was more visible in IC and because the participant don’t like receive information on road. These negative results to “AR concept” can be because the driver nowadays isn’t used to receive information in windshield, neither see the adaptation of the car information to the real environment (as lines and time gap). The simulator environment could to have influence in the preference to “AR concept”, once that there weren’t light effects affecting the information in windshield. It will be important test in real road to understand the light effect in the user experience of driver to receive information in windshield.

In terms of acceptance, in both variables, the results showed significant difference between concepts, so we can assume that the “AR concept” is more useful and left the participants more satisfied comparatively to “IC concept”. The main reasons presented by the participants that gave positive response to “AR concept” was that the blue color was more visible, that the icon was more visible, that the car in “IC concept” didn’t recognize the car position and that there was too much information in “IC concept”. The line keep with negative feedback by some participants in this moment, however others liked. We believe that the negative feedback to the lines in autonomous mode was because the accuracy of the same. If we improve the accuracy of display the information in AR screen, probably the acceptance of most of the participants will increase. We think that the acceptance was better in “AR screen” because when the driver was out of loop (example of secondary task tested: see a movie), with a simple glance could check in windshield that everything was ok, by other side, in IC wasn’t so clear that the autonomous vehicle was detecting the lines and the car ahead.

In terms of awareness situation, the results showed significant difference between concepts. Participants were more awareness in “AR concept” comparatively to “IC concept” because they found the information clearer to understand. The change of color (yellow to blue) was what helped more the participants to know that AD was activated in “AR concept”, followed by the message “AD activated”. All the other items were noticed by less than 1/5 of participants, where we can include the AD icon. The design, position and size of the icon maybe explain the fact of have no noticed. In “IC concept” what helped more the participants were the blue color, followed by the change of color. The message in this concept was noticed by only ¼ of the sample. These results showed that when the visual information was displayed in IC, sometimes wasn't noticed, so as expected was clearer to understand that AD was activated in "AR concept". The human factors team of CTAG used the change of color, message "AD activated" and AD icon to help the awareness situation of the driver about this moment, however neither all the participants noticed that information. Maybe the quantity of new information's to the participants could influence this miss of information during the experimenter interview after each participant test the concept. By other side, the change of color in this first steps to AD could be enough, however could concern other problems in the future such as a change of color in the display by some internal problem to be associated wrongly with an activation of autonomous driving.

During autonomous mode, we evaluated the driver confidence. In terms of confidence, the results showed a trend to "AR concept" again. The main reasons presented by the participants that felt more confidence in "AR concept" during autonomous mode were that the information in windshield didn't distract, the lines gave more perception of color, the info appeared closer of the driver eyes, see the same than the AV is seeing, showing that the car was working well, that the IC didn't call driver attention and that wasn't necessary to force take the eyes of road to obtain information. These results can be explained in fact of the driver with "AR concept", the information appears over the real road information, so the driver had the awareness process facilitated. When the information appeared in IC, the driver needed to get information in IC and after try translate to the real road, making the process more complicated. During the learning phase with autonomous vehicles, the augmented reality can be seen as a mediator to the drivers increase their trust in autonomous driving.

In give back moment, we evaluated the driver preference, acceptance, awareness situation, timing aspects and reaction types. In terms of preference, the results showed significant difference between concepts, so we can assume that the user experience was better in "AR concept" (25/29 participants). This findings are according Park and Park (2019) expectations, where they argued that the HUD systems have a potential to improve the driver experience. The main reasons presented by these participants were that after listen the sound, what they do first is look to the road, so they saw first the information in "AR concept", that the participants consider an important moment, so the information should appears on the road, that the information was very clear, that appears right where they were looking, that when you are alert, what you do first is look to the road, that if you look to the IC in this moment, you're losing information of road and some participants argued that didn't see visual information in IC. These results can be explained by the localization of information, once that when there is an alert situation (as the give back), the driver has the tendency to look to the road, so if the information appears in windshield as in "AR concept", the driver didn't need "lose" time looking to the IC, so their preference was better for AR, as verified in this test. The participants that preferred the "IC concept" (2/29) argued as main reason that the information in IC appeared close of the eyes in the moment of see a movie in CC. In fact, the IC was closer of the CC comparatively to windshield, however the normal behavior of the driver when listen a sound is look to the road and only after to the IC. Maybe these results show us a participant that already knew the function very well and the level of trust it's already good to AD.

In terms of acceptance, in both variables, the results showed no significate difference between concepts. These results can be explained by the fact of the sound be the main help to the drivers, so the visual information was to the second plan.

In terms of awareness situation, the results showed no significate difference between concepts. In both concepts were very clear understand that the car was asking the control. In both concepts, what helped more the participants were the sound. In "AR concept" the second big help was the red color and in "IC concept" was the message "take control". The items of SW, pedal, foot and hands were noticed by some participants too. The GB tested was always because an end of traffic jam, so the participants already was waiting for the car alert to take control and maybe that influenced positively the driver awareness. The sound wasn't a "bip" as in previous moments (Availability and activation), but a woman voice saying, "take control" more a countdown by voice and that leave the participants without doubts about the action that they should do. A participant in each concept didn't see any visual information, maybe because the reaction time was quick and had no time to see the information about this moment.

In terms of reaction time, we evaluated the "hands on time" (Time since appeared the warning until the driver put the hands on the SW), the "take over time" (Time since appeared the warning until the driver put the hands on the SW and the foot on the brake/accelerator) and the possible influence of ST in these reaction times. The findings suggest that supporting the driver in his information processing by providing AR information does not have a significant effect on takeover times. This results are in line with previous research (Lorenz et al., 2014).

About the Hands Over Time, the results showed no significate difference between concepts in general. The mean in "AR concept" was 1,94s and in "IC concept was 2,00s. This range of time is in line with the results of previous research (Gold et al., 2013; Lorenz et al., 2014). When the driver was out of loop (seeing a movie), the results showed no significate difference between concepts to HOT too (M= 2,08s in AR and M=2,28s in IC). When the driver eyes were on the road, the results showed no significate difference too (M= 1,80s in AR and M= 1,73 in IC). We only tested the GB in end of traffic jam, and that could influence the faster reaction times obtained in this study. The level of engagement in the ST was different among the participants.

About the TOT, the results showed no significate difference between concepts in general. The mean in "AR concept" was 2,38s and in "IC concept was 2,44s. This range of time is in line with the results of previous research (Gold et al., 2013; Lorenz et al., 2014). When the driver was out of loop (seeing a movie), the results showed no significate difference between concept to HOT too (M= 2,61s in AR and M=2,85s in IC). When the driver eyes were on the road, the results showed no significate difference too (M= 2,13s in AR and M= 2,02 in IC). We only tested the GB in end of traffic jam, and that could influence the faster reaction times obtained in this study. The level of engagement in the ST was different among the participants.

In deactivation moment, we evaluated the driver preference and the awareness situation. In terms of preference, the results showed significate difference between concepts, so we can assume that the user experience was clearly better in "AR concept" (21/29 participants). This findings are according Park and Park (2019) expectations, where they argued that the HUD systems have a potential to improve the driver experience. The main reasons presented by these participants were that they didn't see the text in IC option, only in AR concept, that the information was more accessible, clean and direct in AR concept, that it's possible see more color and because the information appeared in their field of view. Most of these participants didn't distributed the totally of points to "AR concept" (10 Points to "AR concept" and 0 points to "IC concept") because the most important in this moment to the participants were the change of color and that was visible in both concepts. The participants that preferred "IC concept" (6/29) argued as main reasons that they had more yellow color in IC option, that they are get used to receive information in IC, that the text in OA was too small and that the lines were invasive. These results are influenced by previous experiences in automation, where the drivers are get use to the IC and no to the windshield. As expected, some participants preferred the comfort zone and didn't accept receive information in windshield. Would be curious compare these concepts tested with new drivers, that didn't have previous experience with get information in IC.

In terms of awareness situation, the results showed no significate difference between concepts. In both concepts, the participants founded the information clearer to understand. In both concepts, the change of color (blue to yellow) was what helped more the participants to know that AD was deactivated, followed by the physical response of the car. All the other items were noticed by less than 1/5 of participants, where we can include the AD icon and the message "AD deactivated". In "AR concept" the disappearance of the icon was noticed by 5 participants, and by 1 in "IC concept". The main help to improve the awareness situation of the drivers (AD icon) weren't almost noticed, mainly in "IC concept". The localization and form of the AD icon in IC can explain these results. By other side, in "AR concept", can be explained by the size and form. Two participants in "IC concept" mentioned that didn't see nothing about this moment, and this show us a problem in the information displayed in IC and give strong to "AR concept", where the information about this moment was displayed in OA.

In rear end collision, we evaluated the types of behavior and reaction times. In terms of types of behavior, the results showed better results to "AR concept" with warning comparatively to "IC concept" with warning. The safest behavior, braking and steering, was more frequent in the "AR concept" with warning condition. In terms of reaction time, the results showed shorter times to "IC concept" with warning, comparatively to "AR concept" with warning. Two possible explanations for these results are: 1) This higher reaction times in "AR concept" with warning can be explained by the fact that participants are not used to receive warnings in windshield and seeing it like a surprise, so the time to interpret the warning provoke an increase of reaction time or 2) The visual warning projected in windshield may create a false illusion that the obstacle is far than it is in reality. If we assume that the explanation for these results are the first option, with habituation the drivers could become faster receiving this kind of warning projected in windshield. For the second option, more design options of the square shape around the obstacle may be tried in future investigations.

7. Conclusion

Recent announcements that manufactures will soon sell self-driving cars raise hopes that autonomous vehicles will quickly solve many transportation problems and several car manufacturers proposed many developments and commercialization plans about head-up displays (HUD). This technology creates a new way for interactions between the driver and the vehicle (Phan et al., 2016). With an expected growth of 758 percent in the next 8 years (IHS iSuppli, 2013) will put a great demand on the car manufacturers to supply new technical solutions and functionality together with new ways of user interaction and design of user. However, the HUD have concern other problems to the driver, so the augmented reality can be a help to solve that problems. The information projected in windshield can increase the acceptance, trust and awareness situation of the driver to the autonomous system, once the driver can see the same information that the autonomous car is seeing. This thesis tried make a connection between the new generation of cars and displays. The objective of the current study was to investigate drivers' interactions with a novelty AR display and compare with the current displays in the market during manual mode, autonomous driving level 3 (SAE, 2016) and the transitions between modes.

Results showed that, during manual mode, in terms of user experience the participants preferred signifficatly "AR concept" comparatively to "IC concept". Appears all the car information in operational area was the main justification to this difference. The participants after experimented receive the car information there, didn't miss the information in instrument cluster. The lines in "AR concept" was seen as negative, more distracted than useful. In terms of confidence, "AR concept" showed better results. The participants argued that felt more confident in "AR concept" because they could keep the eyes on the road getting car information and that appeared in a comfortable zone. These results suggested that the operational area improve the user experience of driver and explain a new expansion of HUD expected. However, the quantity of information displayed there should be take into account. New questions can appears, as without instrument cluster, where the fuel and car temperature should appears or should this information always stay visible.

Results showed that, during availability moment, in terms of user experience, the participants preferred signifficatly "AR concept" comparatively to "IC concept". The main reasons were the speed to get the information and the zone where appeared the information. In terms of usefulness, results showed difference significatly favoring "AR concept". In terms of satisfaction, results showed no significate difference between concepts. The information that helped more the participants in this moment was the sound and the visual information more noticed was the message "AD available" in both concept. The participants founded clearer significatly to understand that AD was available in "AR concept", so we can assumed that "AR concept" leave the participant more aware comparatively to "IC concept". The icon was noticed by few participants in this moment, and didn't stayed clear the reason for that. The icon form, position, size and time of this moment could explain this results. Future studies should focus in answer to this doubt. As we were in a simulator environment, no sounds competed with AD sound, so future studies should take into account environment sounds or radio sound to check if the sound keep with the same good effect to alert the driver that AD was available.

Results showed that, during activation moment, in terms of user experience, the participants preferred signifficatly "AR concept" comparatively to "IC concept". The main reasons were that was clear understand that AD was activated, that they could see the same information than the vehicle and that appeared right where the participants were looking. In terms of acceptance (usefulness and satisfaction), results showed difference significatly favoring "AR concept". The information that helped more the participants in this moment was the change of color, followed by message "AD activated" and blue color respectively in "AR concept". In "IC concept" what helped more the participants were the blue color, followed by change of color. The participants founded clearer significatly to understand that AD was activated in "AR concept", so we can assume that "AR concept" leave the participant more aware comparatively to "IC concept". The icon was noticed by less of ¼ of participants isn't clear the reason for that. The participants argued that in autonomous driving felt more confident in "AR concept" because they could see the same information than the car (lines and time gap). Logic of lines in AR area during lane change weren't evaluate, so future studies should study that. The design of the lines and time gap wasn't evaluated, however a user centered design should be fulfilled.

Results showed that, during the give back moment, in terms of user experience, the participants preferred signifficatly "AR concept" comparatively to "IC concept". The main reasons present by participants were that the information appeared right where they were looking, that when you are alert or hear a sound, what you do first is look to the road and that if you look to the IC in this moment, you're losing information of road. We can conclude that in important moments, as during this moment, the participants prefer receive information on the road. In terms of acceptance (usefulness and satisfaction), results showed no difference significatly between concepts. Both concepts had very positive means of acceptance. The information that helped more the participants in this moment was the sound in both concepts. In “AR concept”, the second information more noticed was the red color, followed by the message “take control. In “IC concept” the second information more noticed in this moment was the message “take control”, followed by the red color and icon of SW. The participants founded very clear to understand that the car was asking the driver control and the results showed no significitve difference between concepts. We can assume that the most important in this moment was the sound in both concept, where the participants alteady knowed what they should do. In terms of timing aspects, the results showed no significative difference between concepts during “hands on reaction time” and “take over request reaction time”. About the reaction types, in both concepts, most of the participants take control using the “acelerator pedal + hands on SW” during the end of traffic tested in simulator. We can conclude that display information in windshield during the take control improve the user experience, however in terms of acceptance, awareness situation and reaction times no difference was visible between concepts. During a give back because an end of traffic, the normal behavior of the drivers to resume the control is put the hands of the steering wheel and the foot on acelerator.

Results showed that, during the deactivation moment, in terms of user experience, the participants preferred signifficatly “AR concept” comparatively to “IC concept”. The main reasons present by participants were that they didn’t see the text in “IC concept”, that the information was more accessible, clean and direct in “AR concept” and because the information appeared in the field of view of the drivers. The information that helped more the participants in this moment was the change of color, followed by the physical response of the car. Disappears the icon and the message “AD deactivated” was mentioned by few participants and future studies should found an explanation to this fact. The participants founded very clear to understand that the autonomous driving was deactivated and the results showed no significitve difference between concepts. We can conclude that in this moment is more important the psysical response of the car than the information showed in the displays, and for that was very clear understand the state of the function in both concepts.

The wide variety of situations encountered by drivers and the flexibility of displays in what and how they may be able to highlight areas of interest leave many opportunities for additional research into the effects of Augmented reality screen on driver attention, trust, SA. The information displayed in AR screen can have an important role the cars of the future (autononomous vehicles), and that should be studied in detail.

Results showed, that during the rear end collision, in terms of reaction types, the “AR concept” showed safer behaviors comparatively to “IC concept”. However, in terms of reaction times, “IC concept” show better results. Due to small sample in the study we can not draw a final conclusion concerning this more objective measures.

In terms of future work, in manual mode, it’s important to define the information that should be displayed in OA and the size and position of that information. During the availability, an interesting topic to study is the possible influence of car music in the sound of availability advise. In this moment too, should be good understand in detail the reason for the icon doesn’t be noticed, and test the possible influence of the size, position and form. The size and content of the text should be studied in detail too. About the activation moment, further logic of lines should be tested, when the AV detects an obstacle or when the AV wants change line. The information that the driver really need during autonomous driving should be studied too. The information of give back was clear, however should be tested in a situation where after the GB appears an obstacle and it’s really important the driver attention. During the deactivation, the icon and text were few noticed, so further investigations about the reasons of the same should be developed. Other topics that could be studied are the influence of age and driver factors in the acceptance of receive information in windshield.

It’s important validate these results in real road, as well as in conditions where the participant remain in autonomous driving during long periods of time, so the situational awareness is worst.

In summary we can conclude that display information in windshield (AR) improve the user experience in all the moments. The confidence is equal positively influenced by information on windshield, both in manual and autonomous mode, comparatively to display information in instrument cluster. In terms of awareness situation, display information on windshield help more the drivers during the availability and activation of the function. During the give back and deactivation the location of the information don’t improve the situational awareness. In terms of acceptance, only during the activation of the function the information in windhshield is more accept comparatively to instrument cluster. Display information in windshield during giveback don't improve the reaction times neither the change the type of behavior comparatively to instrument cluster. During rear end collision, augmented reality concept showed higher reaction tymes however safe behaviors was more frequent in the windshield than with instrument cluster concept.

In general, we conclude that there is a clear advantage of augmented reality screen comparatively to instrument cluster and that advantage could inscrease when the people get used to this way of presenting information and also when the technical problems of the lines are solved. This advantages is true for subjective variables and for the behavioral reactions in the rear end collision (which is a limit throughout the study and not just in this use case study). However, concerning reaction times in the rear end collision situation, there is an disadvantage of augmented reality, that has to be further investigated with larger samples and with design changes of the square around the obstacle because either it is responsible for creating confusion or making the car appear to be further away, creating an evaluation in excess for the time or distance available.

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Appendix 1 – Dato protection

Información básica sobre Protección de Datos (Capa 1) – Videovigilancia

En cumplimiento de la normativa vigente en materia de protección de datos, Reglamento (UE) 2016/679 del Parlamento Europeo y del Consejo de 27 de abril de 2016 (GDPR), Ley Orgánica de Protección de Datos de Carácter Personal (LOPDCP, 15/99), Reglamento de Desarrollo de la LOPDCP (Real Decreto, 1720/2007, de 21 de diciembre), le facilitamos la siguiente información:

Responsable del tratamiento de los datos de carácter personal:	Fundación para la Promoción de la Innovación, la Investigación y el Desarrollo Tecnológico de la Industria de la Automoción de Galicia (**CTAG**), con NIF: G-36. 871.424 y domicilio en Polígono de A Granxa, calle A, parcela 249-250. 36400 Porriño (Pontevedra). rgpd@ctag.com
Finalidades del tratamiento:	La finalidad del tratamiento es la **gestión de los datos de los asistentes a pruebas** que colaboran en las distintas pruebas o ensayos para los varios estudios organizados por la empresa.
Legitimación:	Consentimiento del interesado para cada finalidad específica.
Destinatarios:	No se realizan cesiones, salvo las que sean necesaria para el cumplimiento de una obligación legal del responsable
Derechos:	Tiene derecho a acceder, rectificar y suprimir los datos, así como otros derechos, como se explica en la información adicional.
Información adicional:	Puede consultar la información adicional en la Política de Privacidad y Protección de Datos que figura en la página web de la empresa.

Consentimiento para el tratamiento de sus datos personales

☐ El/la interesado/a declara ser mayor de 16 años y presta su consentimiento para el tratamiento de sus datos de carácter personal, de acuerdo con la información facilitada y las condiciones expuestas en la Política de Protección de Datos. Así mismo, declara ser exactos y veraces los datos facilitados, y se obliga a comunicar por escrito a Fundación para la Promoción de la Innovación, la Investigación y el Desarrollo Tecnológico de la Industria de la Automoción de Galicia (CTAG), Polígono de A Granxa, calle A, parcela 249-250. 36400 Porriño (Pontevedra), cualquier variación o modificación que se produzca en los datos antes referidos.

Firmado:

Nombre:

Fecha:

Appendix 2 – Informed consent

CONSENTIMIENTO INFORMADO AR E ID

PROPÓSITO

Este estudio forma parte del proyecto de investigación "Autonomous vehicle". Le invitamos a participar en el mismo como conductor autorizado. El objetivo de este estudio es avaluar la interacción humana con el vehículo, en conducción manual y conducción autónoma.

PROCEDIMIENTO

El estudio constará de una única sesión de aproximadamente 1 hora y 30 minutos (conducción + entrevistas).

En el simulador de conducción, primero se llevará a cabo una breve sesión de entrenamiento para que se familiarice con él. Posteriormente procederá a conducir por un escenario siguiendo las indicaciones que el experimentador le proporcione.

Durante la simulación estará acompañado por un experimentador, además de mantener la comunicación con la Sala de Control en todo momento.

Se grabará audio y video durante las sesiones, así como datos de simulación.

SISTEMAS DE SEGURIDAD DEL SIMULADOR DE CONDUCCIÓN

Antes de proceder a probar el simulador, lea atentamente las siguientes indicaciones y en caso de tener alguna duda consulte al personal técnico.

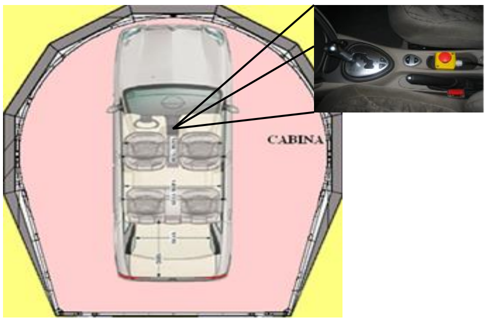
Antes de empezar la simulación:

Debe cerrar todas las puertas del vehículo. Éstas tienen un sensor y no arrancará la simulación mientras alguna permanezca abierta.

Debe abrocharse el cinturón de seguridad. El Simulador de Conducción de CTAG cuenta con una plataforma dinámica que simula los movimientos de un coche real, por lo tanto, no abrocharse el cinturón puede ser peligroso.

El técnico que suba con usted le indicará la posición de la seta de emergencia. Asegúrese de que puede alcanzarla sin problemas.

Pregunte cualquier duda que tenga al personal técnico.



Posición de la seta de emergencia en el interior del vehículo instrumentado.

Durante la simulación:

En todo momento tiene comunicación directa con la sala de control a través de un micrófono instalado en el coche. Si en cualquier momento empieza a encontrarse mal (mareos, náuseas, etc.) u observa cualquier anomalía, comuníquelo inmediatamente.

Si por cualquier razón quisiese detener la simulación, puede hacerlo de tres formas:

- Comunicándoselo a uno de los dos técnicos (el que lo acompaña o el que se encuentra en la Sala de Control);
- Pulsando la seta de emergencia;
- Abriendo una de las puertas del coche.

Después de la simulación:

Cuando la simulación se detenga, ya sea a causa de una parada de emergencia o no, no salga de la cabina hasta que se lo indique el personal técnico.

Antes de salir de la cabina compruebe que el indicador de "posición de escalera" esté iluminado en verde.

En cualquier caso, siga siempre las instrucciones del equipo técnico y pregunte cualquier duda que pueda tener.

RIESGOS

La conducción en entornos virtuales (simulador de conducción) puede conllevar los siguientes efectos secundarios:

- Lagrimeo;
- Vómitos o Arcadas;
- Náuseas;
- Dolor de cabeza;
- Entre otras cosas.

Por este motivo no es aconsejable el uso de esta tecnología en personas que sufran o hayan sufrido crisis epilépticas, problemas cardiacos, o aquellas que hayan tomado una copiosa comida momentos antes. De igual forma, si está embarazada o cree que pudiera estarlo no debe participar en esta prueba.

Las pruebas en el simulador de conducción no se deben realizar si está bajo el efecto de cualquier sustancia que pueda afectar a su rendimiento (droga, alcohol o medicamentos).

COSTES Y COMPENSACIÓN

La participación en este experimento no implica ningún coste para el sujeto, así como tampoco una compensación. El sujeto no obtendrá beneficios personales independientemente de la explotación de los resultados que realice el centro o cliente.

CONFIDENCIALIDAD

En cumplimiento de lo dispuesto en el Reglamento Europeo 2016/679 General de Protección de Datos, te informamos que trataremos los datos que nos facilitas al registrarte para:

Realizar el estudio de investigación "AR E" dentro del proyecto vehículo autónomo.

Ver anexo 1

CTAG puede incluir estos datos en informes finales u otras publicaciones o medios (para fines científicos, educaciones, promocionales, legislativos o de investigación). Estos datos podrán ser utilizados de forma individual o conjuntamente con los de otros sujetos, pero no serán presentados de forma que permitan la identificación personal. Está prohibido compartir información de este estudio durante los próximos 5 años.

PARTICIPACIÓN VOLUNTARIA

La participación en este estudio es voluntaria. Puede elegir no tomar parte en él. Si está de acuerdo en participar en este estudio, tiene la posibilidad de abandonarlo en cualquier momento. Si no decide participar o abandona, su decisión no tendrá ninguna penalización o pérdida de beneficio.

La participación en el estudio implica que conoce y cumple los requisitos mínimos para poder participar en el mismo:

- Tener entre 20 y 75 años (inclusive);
- Poseer licencia de conducción en vigencia;
- Tener más de dos años de experiencia como conductor;
- No estar bajo el efecto de ninguna sustancia que pueda afectar a tu comportamiento como conductor.

Bajo ciertas circunstancias, su participación en el estudio puede terminar sin su consentimiento si los investigadores del proyecto lo consideran oportuno.

ACEPTACIÓN DEL CONSENTIMIENTO INFORMADO

Su firma indica que ha leído este documento, le han explicado el estudio, respondido correctamente a sus preguntas y está de acuerdo en participar en el estudio denominado "AR E"

En Porrino a ______ de _____________ de 2018

Fdo. D. /Dña. ___________________________

(Participante)

He explicado y comentado este documento con el sujeto. Creo que el participante ha entendido los riesgos, beneficios y procedimientos existentes en la participación de este estudio de investigación.

En Porriño a ______ de _____________ de 2018

Fdo. D. /Dña. ___________________________

(Investigador)

Appendix 3 – Instructions

Recepción del participante y presentación del estudio

Instructions out the vehicle

- Bienvenido/a y gracias por participar en este estudio. Apreciamos mucho tu participación.
- Antes de empezar, te explicaremos cómo conducir el coche autónomo y haremos una primera conducción en el simulador. Si todo vá bien, continuaremos con la prueba. Antes de participar también te explicaremos el consentimiento informado que es obligatorio firmar antes de participar. En este consentimiento explicaremos las instrucciones de seguridad a tener en cuenta y cuáles son las condiciones para participar en el estudio. Si no está de acuerdo con el consentimiento informado, no dudes en hacérnoslo saber, la participación en el estudio es totalmente voluntaria.

El participante rellena el consentimiento informado

- Recuerda que no puedes llevar tu móvil durante la prueba a menos que esté apagado o en modo avión.
- Por favor, adapta el asiento hasta que te sientas cómodo.
- El objetivo del estudio es evaluar el HMI (INTERFACE) durante la conducción y la interacción humana con las pantallas.
- Nos gustaría saber tu opinión sobre el hecho de conducir este coche en este estudio. Durante la prueba se registrará cualquier cosa que nos quieras decir acerca de la experiencia de conducción autónoma, esta es la razón por la que se grabará el contenido de la prueba (audio y video). Apreciamos tu opinión como usuario para mejorar el sistema que vas a probar en el estudio. Con este objetivo, queremos que expreses en voz alta lo que te venga a la mente mientras conduces. Esto podría incluir lo que estás pensando, haciendo y sintiendo.
- Ahora, te voy a explicar cómo **funciona la función autónoma** que irás a probar en el estudio.

Presentación de la función

- Se basa en una situación de atasco y establece un límite de velocidad y no permite el cambio de carril.
- El vehículo conduce de manera completamente autónoma, acelerará y frenará en función de la velocidad del coche que tenga delante.
- No hay riesgo de accidente, el vehículo controla todo: velocidad, volante, obstáculos, etc.
- Sin embargo, si por alguna razón el vehículo no es capaz de controlar algo, te pedirá que retomes el control manual. Siempre que el coche te pida el control, debes asumir el mismo. Para eso tienes de poner las manos en el volante y el pie en freno o acelerador para volver a la conducción manual.
- En algunos momentos el sistema te informará que la función autónoma está disponible para su activación. Para este estudio, siempre que la función esté disponible deberá ser activada con un botón (decir dónde está el botón).
- ¿Alguna duda?
- Ahora, te voy a explicar **las instrucciones generales de la prueba**.

Instrucciones genérales de la prueba

- El test está formado de dos partes: La fase de aprendizaje, para que te adaptes y entiendas el funcionamiento del vehículo y estés más preparado para las tareas secundarias; y la fase de test, que constituye la prueba principal.
- Debes conducir como lo haces habitualmente con tu vehículo particular. Debes mantener una velocidad constante de 120 km / h durante la conducción manual, excepto cuando las condiciones de tráfico no lo permiten. Durante la prueba debes respetar el código de tráfico en todo momento. Si en algún momento hicieres un cambio de carril, utiliza los intermitentes;
- Habrá momentos que conducirás en manual y otros momentos que conducirás en autónomo.

- Durante el test te pediré en algunos momentos que realices tareas secundarias. Durante la conducción autónoma la tarea secundaria será ver una película y durante la conducción manual será hacer una cuenta.
- Si en algún momento no te sientes bien dilo y pararemos la prueba. Eres libre de dejarla en el momento que consideres.
- ¿Tienes alguna duda?
- Éste es un coche automático. ¿Sabes cómo conducirlo?
- ¿Tienes alguna duda?
- Vamos ahora empezar con la fase de aprendizaje.
- Vamos empezar en modo Manual.

El participante hace la fase de entrenamiento en el simulador

- Hemos terminado la fase de aprendizaje y ahora dará comienzo la prueba.
- No tienes que girar la cabeza para me contestar, apenas tienes de responder en voz alta. Yo solamente voy aquí detrás para no interferir con la prueba.
- Si no te sientes bien en algún momento, por favor, dímelo.
- ¿Alguna duda?
- ¿Estás listo/a para empezar?

El participante da inicio a la fase de teste

Appendix 4 – Sample questionnaire

Como parte de este estudio, es necesario recopilar información de cada participante. Las siguientes preguntas nos permitirán conocer diversa información acerca de su salud, así como información de su conducción. Por favor, lea las preguntas con calma y marque solo una opción a no ser que se indique lo contrario. La participación es voluntaria y puede no contestar cualquier pregunta si considera que es ofensiva o simplemente no quiere responderla.

Muchas gracias por su colaboración.

Edad:

Genero:

1. Edad: ____________

2. Género:

Hombre ◯

Mujer ◯

3. Nivel educativo:

Sin estudios ◯

Primaria ◯

Secundaria ◯

Formación profesional ◯

Diplomatura (3 años) ◯

Grado/ Licenciatura (4/5 años) ◯

Más de 5 años ◯

4. Área formación (Ej: Ingeniería Informática): ____________

5. Ocupación (Ej: Desarrollador software) ____________

6. Numero de hijos:

0 ◯

1 ◯

> 2 ◯

7. ¿Eres daltónico/a?

Sí ◯

No ◯

8. ¿Tiene algún problema de audición?

Sí ◯

No ◯

9. ¿Usa gafas o lentillas?

Sí ◯

No ◯

10. Lugar de trabajo:

Ciudad ◯

Entorno rural ◯

Ambos ◯

11. Lugar de residencia:

Ciudad ◯

Entorno rural ◯

12. Experiencia como conductor (Años): ____________

13. Carnet de conducir (diferentes opciones disponibles):

A1 ☐

A ☐

B1 ☐

B ☐

C1 ☐

C ☐

D1 ☐

D ☐

14. ¿Con qué frecuencia condujo el año pasado?

Al menos una vez a la semana ◯

Más de una vez a la semana ◯

Al menos una vez al día ◯

15. Aproximadamente ¿Cuántos km hace al año?

<10.000 km ◯

10.000 – 15.000 km ◯

15.001 – 20.000 km ◯

>20.000 km ◯

16. Entorno en el que suele conducir:

Carreteras principales ◯

Carreteras rurales ◯

Carreteras urbanas ◯

Autopista ◯

Autovía ◯

17. ¿Qué tipo de trayectos hace habitualmente? (diferentes opciones disponibles):

De casa al trabajo ☐

Viajes de trabajo ☐

Para ir de compras, al gimnasio, salir, etc… ☐

Vacaciones/Fin de semana ☐

18. ¿Cómo calificas el tráfico durante el trayecto?

Grandes atascos ◯

Atasco ◯

Tráfico intenso pero con fluidez ◯

Fluido ◯

19. Marca, modelo de vehículo y año (Ej: Toyota Yaris - 2016): ____________

20. ¿Tu vehículo tiene HUD (Heads up display)?

Sí ◯

No ◯

21. ¿Tu vehículo tiene cambio automático?

Sí ◯

No ◯

22. ¿Cómo describiría su conducción?

Deportiva ◯

Económica ◯

Calmada ◯

Ecológica ◯

Cuidadosa ◯

Distraída ◯

23. ¿Ha usted usado alguna vez esta asistencia, con qué frecuencia?

	No lo conozco	Nunca lo he usado	Lo he usado alguna vez	Lo uso con frecuencia	Lo uso mucho
Control de crucero	○	○	○	○	○
Control de crucero adaptativo	○	○	○	○	○
Limitador de velocidad	○	○	○	○	○
Asistente de mantenimiento de carril	○	○	○	○	○
Detección de ángulo muerto	○	○	○	○	○
Asistente de cambio de carril	○	○	○	○	○

24. ¿Ha participado en algún estudio relacionado con conducción autónoma antes?

Sí ○

No ○

25. ¿Es usted un seguidor o está interesado en las nuevas tecnologías?

Sí ○

No ○

Appendix 5 – Questionnaire before learning phase

Q0.1 ¿Cómo calificarías tu nivel de confianza para la conducción autónoma?

Nada confiante Muy confiante

1 2 3 4 5

Q0.1.1 ¿Por qué? ____

Appendix 6 – Questionnaire after learning phase

Q0.2 ¿Cómo calificarías tu nivel de confianza para la conducción autónoma?

Nada confiante Muy confiante

1 2 3 4 5

Q0.2.1 ¿Por qué? ____

Appendix 7 – Questionnaire after test phase 1 and test phase 2

ID Participante: ______

Fecha: ______

Concepto: AR ◯ IC ◯

Counterbalancing: ______

Cuestiones generales

Q0.3 ¿Cómo calificarías tu nivel de confianza para la conducción autónoma?

Nada confiante Muy confiante

1 2 3 4 5

Q0.3.1 ¿Por qué? ____

AVAILABILITY

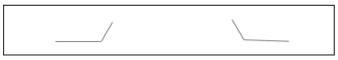
Q1. ¿Por favor, dime tu opinión sobre recibir la disponibilidad que tu viste en acción?

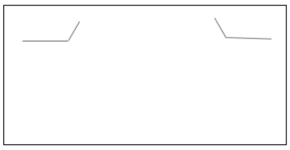
Útil	1	2	3	4	5	Inútil
Agradable	1	2	3	4	5	Desagradable
Malo	1	2	3	4	5	Bueno
Amigable	1	2	3	4	5	Molesto
Efectivo	1	2	3	4	5	Superfluo
Irritante	1	2	3	4	5	Placentero
Buen asistente	1	2	3	4	5	Innecesario
Indeseable	1	2	3	4	5	Deseable
Aumenta el estado de alerta	1	2	3	4	5	Induce al sueño

Q2. ¿Cómo supiste que la conducción autónoma estaba disponible? _____________

Q3. ¿Qué viste? _____________

Q4. ¿Dónde viste la información?





Q5. ¿Cuán claro fue para ti entender que la conducción autónoma estaba disponible?

Nada claro				Muy claro
1	2	3	4	5

Q5.1. ¿Por qué? ______________

ACTIVATION

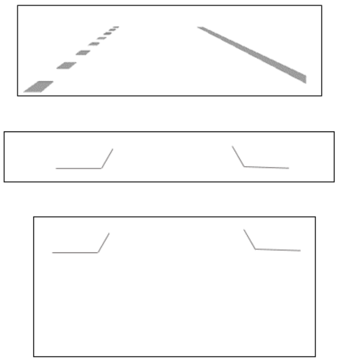
Q6. ¿Por favor, dime tu opinión sobre recibir la activación que tu viste en acción?

Útil	1	2	3	4	5	Inútil
Agradable	1	2	3	4	5	Desagradable
Malo	1	2	3	4	5	Bueno
Amigable	1	2	3	4	5	Molesto
Efectivo	1	2	3	4	5	Superfluo
Irritante	1	2	3	4	5	Placentero
Buen asistente	1	2	3	4	5	Innecesario
Indeseable	1	2	3	4	5	Deseable
Aumenta el estado de alerta	1	2	3	4	5	Induce al sueño

Q7. ¿Cómo supiste que la conducción autónoma estaba activada? _____________

Q8. ¿Qué viste? _____________

Q9. ¿Dónde viste la información?



Q10. ¿Cuán claro fue para ti entender que la conducción autónoma estaba activada?

Nada claro Muy claro

1 2 3 4 5

Q10.1. ¿Por qué? ______________

GIVE BACK

Q11. ¿Por favor, dime tu opinión sobre el momento en que el coche te pidió el control?

Útil	1	2	3	4	5	Inútil
Agradable	1	2	3	4	5	Desagradable
Malo	1	2	3	4	5	Bueno
Amigable	1	2	3	4	5	Molesto
Efectivo	1	2	3	4	5	Superfluo
Irritante	1	2	3	4	5	Placentero
Buen asistente	1	2	3	4	5	Innecesario
Indeseable	1	2	3	4	5	Deseable
Aumenta el estado de alerta	1	2	3	4	5	Induce al sueño

Q12. ¿Cómo supiste que el coche te estaba a pedir el control? _____________

Q13. ¿Qué viste? _____________

Q14. ¿Dónde viste la información?_____________

Q15. ¿Cuán claro fue para ti entender que el coche te estaba a pedir el control?

Nada claro				Muy claro
1	2	3	4	5

Q15.1. ¿Por qué? _____________

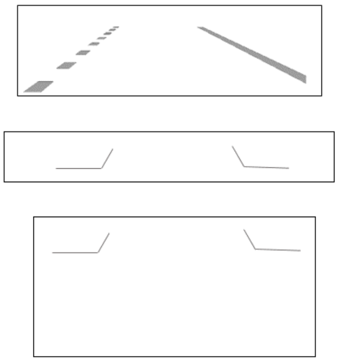
DEACTIVATION

Q16. ¿Cómo supiste que la conducción autónoma estaba desactivada?

____

Q17. ¿Qué viste? ______________

Q18. ¿Dónde viste la información?



Q19. ¿Cuán claro fue para ti entender que la conducción autónoma estaba desactivada?

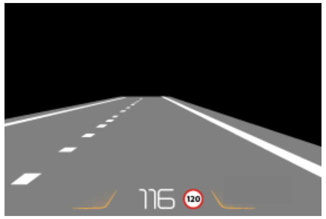
Nada claro				Muy claro
1	2	3	4	5

Q19.1. ¿Por qué? ______________

Appendix 8 – Final interview

ID Participante: ______

Fecha: ______

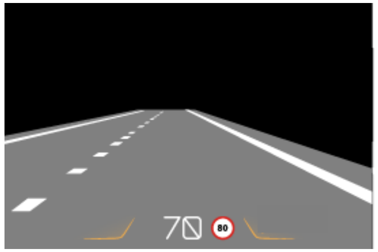
Manual	
Q20	
Por favor, distribuye 10 puntos entre las dos opciones de acuerdo con tu preferencia para que sepas que estas em modo manual. **[La suma de las puntuaciones debe ser 10]**	
Opción 1	Opción 2
  	
_____ puntos	_____ puntos

Q20.1	
¿Por qué?	
Q21	
¿En cuál opción te sentiste más confiado durante la conducción manual?	

Q22

Por favor, distribuye 10 puntos entre las dos opciones de acuerdo con tu preferencia para ver que la conducción autónoma estaba disponible. [La suma de las puntuaciones debe ser 10]

Opción 1



_____ puntos

Opción 2

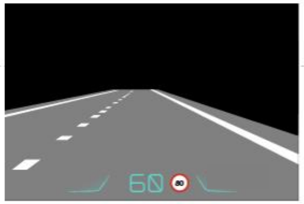
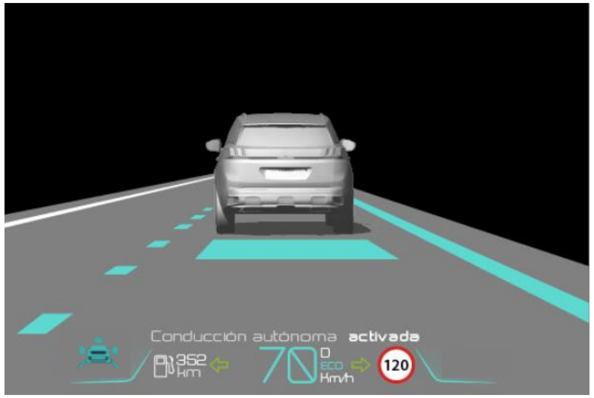
_____ puntos

Q22.1

¿Por qué?

Activación

Q23

Por favor, distribuye 10 puntos entre las dos opciones de acuerdo con tu preferencia para ver que la conducción autónoma estaba activada. [La suma de las puntuaciones debe ser 10]	
Opción 1	Opción 2
 	
_____ puntos	_____ puntos

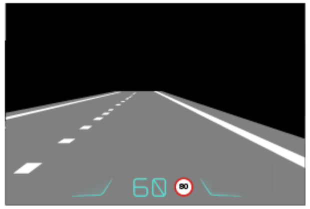
Q23.1

¿Por qué?

Q24	
¿En cuál opción tú te sentiste más confiado durante la conducción autónoma? ¿Por qué?	

Toma del control

Q25

<table>
<tr><td colspan="2">Por favor, distribuye 10 puntos entre las dos opciones de acuerdo con tu preferencia para ver que deberías tomar el control del coche.
[La suma de las puntuaciones debe ser 10]</td></tr>
<tr><td>Opción 1</td><td>Opción 2</td></tr>
<tr><td>

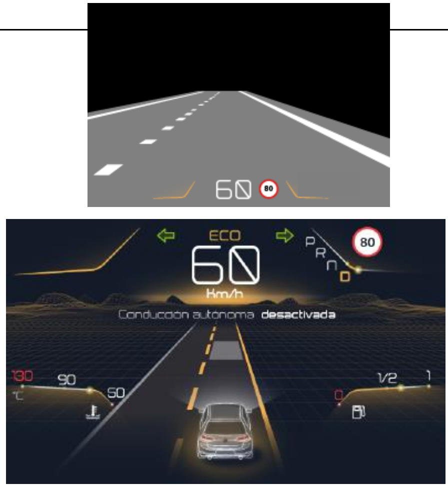

</td><td>
</td></tr>
<tr><td>_____ puntos</td><td>_____ puntos</td></tr>
</table>

Q25.1
¿Por qué?

Desactivación

Q26

Por favor, distribuye 10 puntos entre las dos opciones de acuerdo con tu preferencia para ver que la conducción autónoma estaba desactivado. [La suma de las puntuaciones debe ser 10]

Opción 1	Opción 2
	
_____ puntos	_____ puntos

Q26.1
¿Por qué?