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Master Thesis in Human Factors and Technological Transport systems

Driver's perceptions about the effects of speed regulation systems in the driving task

Autor: **Ana Luísa Barradas Vicente Ferreira**

Júri:

Professora Doutoura Anabela dos Santos Aleixo Simões

Professor Doutor Carlos Marques

Professor Doutor Pedro Ferreira

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Abstract

Speed regulation systems like the cruise control (CC) and the speed limiter (SL) are becoming a standard feature in vehicles nowadays. However, these systems add a certain level of automation to the driving task and so they have the potential to change the way people drive. In order to understand the potential that these systems have in terms of road safety, it is crucial to understand how drivers percept the effects of the systems during the driving task. Then, the aim of the present research was to identify driver's perceptions about the effects of speed regulation systems, more specifically the cruise control and the speed limiter, in the driving task and, to accomplish this goal, a questionnaire was applied. The main findings were that females are more prone to keep speeds equal to the road speed limit, and that when using both, cruise control and speed limiter, drivers are more available to comply with road speed limits. It was also found that the CC has a bigger impact than the SL when it comes to engaging into secondary tasks while driving.

Keywords: Cruise control; speed limiter; drivers' perceptions; questionnaire; road safety.

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Nomenclature

ACC_ Adaptive Cruise Control

ADAS_ Advanced Driver Assistance Systems

CC_ Cruise Control

EU_ European Union

ITS_ Intelligent Transport Systems

IVIS_ In-Vehicle Information and Communication Systems

KB_ Knowledge-based level

RB_ Rule-based level

SA_ Situation Awareness

SB_ Skill-based level

SL_ Speed Limiter

UFOV_Useful field of view

INTRODUCTION

The present study was developed in the frame of the European Project INTERACTION (FP7). The European Project INTERACTION focused on 4 systems (cruise control, speed limiter, navigation system and mobile phone) and the main aim was to identify the patterns of use of these systems for drivers that use them on daily basis.

The present study was based on material developed in the aim of this project, in particular in the survey that was applied to Portuguese drivers. In the frame of the project, the data was treated in more general way, the intention here was to focus only on speed regulation systems (cruise control and speed limiter) and to give meaning to those results in the Portuguese road context.

This document is divided in 4 distinct parts. In the first part, the theoretical framework, the main topics that are going to be discussed in this work are presented. In the first chapter the issue of speed in roads is discussed, along with the main obstacles to speed compliance at European level and at national level. The second chapter presents and describes Intelligent Transportation Systems (ITS), emphasizing the speed regulation systems that are studied, the cruise control and the speed limiter. The third chapter is about the driving task and the driving activity and, there, theories that explain human behaviour while driving are presented. The fourth chapter is about drivers' information processing: here the processes that occur from the perception until the response are explained, giving a special emphasis on the attention topic. The following chapter about automation and behavioural adaptation (chapter five) explains the effects that the automation inside the vehicle might have on the driver, mainly focusing on problems that might occur during the speed regulation systems' use (mental workload, distraction and fatigue). In the sixth chapter, driver variability is addressed focusing on the impact that human differences like age and gender, have on the driving task. In the final chapter, the research questions that were drawn out of the theoretical issues are presented.

In part two of the document the methodology is explained. The methodology applied was split in two different moments: the analysis of the questionnaire data and a second and more complementary part represented by the interviews.

In part three, the results are discussed and related with the theories that were the support on this work to draw recommendations.

Finally, the conclusions are drawn from the results obtained, along with the limitations and proposed improvements for further investigations in the field of this work.

According to European Commission’s white paper (2011), a big concern in the transportation field in the present days and for the future is with no doubt to reduce transport emissions, avoid congestions, turn mobility more sustainable and more energy efficient. New technologies for vehicle and traffic management play an important role in those efforts. Delayed action and timid introduction of new technologies could condemn the European Union (EU) transport industry to irreversible decline. That is why it is more and more important not just to integrate those systems, but to investigate in detail the impact of those systems in the real context.

Nowadays, the research in the field of ITS is mainly focused on systems that are not yet available for consumers or on systems that are only available for a limited range of consumers (e.g. systems that can only be found in high class vehicles), like the case of adaptive cruise control (ACC). It is very important that these systems are investigated before being released in the market, because this will allow knowing more about the implications that these systems have on the driving task and on the driver. However, this didn’t happen for all the ITS that were released for vehicles, as in the case of the speed regulation systems like the cruise control and the speed limiter.

Speed regulating systems are already available in a considerable part of the national car park and there should be a clear understanding about the way they work and the way they should be used. According to the Portuguese Minister Resolution nº 80/2008 (Diário da República Electrónico) about Energetic Efficiency action plan to apply until 2015, one of the main measures and aims to achieve in the transportation field is to have 20% of the national fleet with monitoring equipment such as cruise control. With this kind of measures, we can think that the national car fleet equipped with cruise control will increase in this next years.

The aim of the present research was to identify driver's perceptions about the effects of speed regulation systems (cruise control and speed limiter) in the driving task.

The specific objectives of this research were to understand the role that age and gender plays in the perception of cruise control and speed limiter, to identify the percepted effects of the cruise control and speed limiter in speed limits compliance and finally, to identify if drivers tend to engage more in secondary tasks while using these systems.

This work contributes to the augmentation of the knowledge about how people percept speed regulation systems, more specifically the cruise control and speed limiter, and also assess the needs and measures that could be improved in terms of road safety.

PART I. THEORETICAL FRAMEWORK

Chapter 1. Speeding issue

In 2009, about 35,000 people were killed in road accidents in the 27 member states of the EU (European Commission, 2011). Speed is one of the basic risk factors in traffic (Wegman & Aarts, 2006): higher driving speeds lead to higher collision speeds and, therefore, to more severe injury. Higher driving speeds also provide less time to process information and react to a critical situation, and the braking distance is longer.

Over the years, several studies focused on the relation between speed and crash rate using different approaches but it has been very difficult to relate one to another since it is difficult to isolate speed from other factors that contribute for the crash (Aarts & Van Schagen, 2006). This complexity is the reason for the conditions that influence the relation between speed and road safety hasn’t yet been found.

1.1 Impacts of speed on transport

- **Accidents**

Generally, the number and severity of accidents decrease with decreasing speed. A reduction of the mean speed by 1 km/h can be expected to bring 2 to 3.5 percent reduction in the number of accidents with injuries, and also to reduce to almost half the number of fatalities and accident costs (Baruya, 1998).

- **Environmental effects**

Oxides of nitrogen (NOx) and carbon monoxide (CO) emissions increase with speed. Accelerations can particularly increase emissions. As well, noise increases linearly with speed, when speed exceeds 40–50km/h. (Robertson, Ward, Marsden, Sandberg, & Hammarström, 1998). Speed combined with road infrastructure has the potential to affect the traffic flow, in some situations (e.g. bottleneck roads) high speeds might cause traffic jams. As traffic congestion increases, do fuel consumption and CO2 emissions. Therefore, congestion mitigation programs should reduce CO2 emissions (Barth & Boriboonsomsin, 2008).

- **Vehicle operation and maintenance costs**

When drivers adopt higher speeds the fuel consumption can increase significantly and associated costs will be higher. A vehicle that is constantly traveling at higher speeds will have a higher maintenance, due to a greater friction of components (e.g. tyres, breaking discs, etc.). If drivers reduce sudden accelerations, breakings and adopt lower speeds, the energy needs can be significantly decreased.

1.2 Obstacles to speed management in Europe

- The present values for speed limits are vague, it is not clear if they represent desired levels of speed from the viewpoint of society or from the road transport system. The speed limits should be based on more explicit and systematic criteria (Kallberg, Allsop, Ward, Van der Horst, & Várhelyi, 1998).
- Every European country has a specific system for road classification criteria. These classifications are administratively convenient but, most of the times, they do not reflect the statistical features of the road, such as traffic speed, traffic volume, degree of congestion, road environment and so on (Baruya, 1998).
- It is common for drivers to underrate accident and environmental costs considering the time they save by adopting higher speeds (Kallberg et al., 1998).
- Speed reducing measures are not very popular among drivers (Kallberg et al., 1998).
- Speed limits alone are insufficient for managing speeds at a desired level, even with a good enforcement. In general, it is concluded that speeding is becoming a more frequent phenomenon all over Europe (Kallberg et al., 1998).

1.3 Speed limits in Portugal

In Portugal, roads have different characteristics but the speed limits are not always coherent with the characteristics of the road. Sometimes, we can observe very low speed limits in roads that have characteristics of main roads. If we have a road that has main road characteristics (90 km/h limit) and the speed limit presented is 50 km/h, drivers might ignore it, especially when this situation is happening repeatedly, this might lead the driver to ignore the speed limit presented, since they are not always consistent.

The national project SAFESPEED main aim is to develop a tool to better define the most adequate speed in each road and to find solutions to reduce accidents in Portuguese roads. The researchers of this project believe that there is a real need to define technical criteria to establish roads speed limits in Portugal, since there are some roads where the speed limits are completely misfit (CiênciaHoje, 2012).

1.4 Factors influencing drivers speed choice

Speed behaviour can be driven by several factors. Each of the factors influencing the speed behaviour is briefly described below (Figure 1).

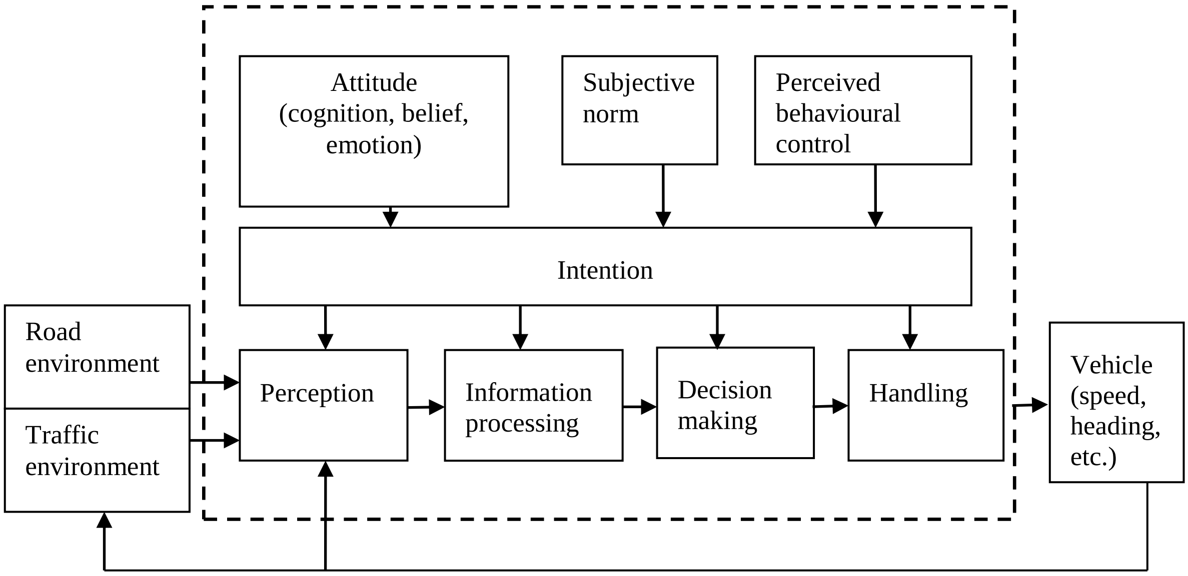

Figure 1. Combined overall behavioral model to indicate factors that influence drivers' speed behaviour (Van der Horst, 1998).

- **Speed and motivation**

Driving speeds are affected by several factors, among those, the most relevant motivational factors are the driving speeds of other road users and others' opinions and reactions towards speed.

Drivers' emotions and moods of the drivers also seem to influence speeds (e.g. fear, anger, boredom, excitement, etc.). In addition, people characteristics also make them experience the surroundings and manage emotions in different ways. For instance, if we think about an aggressive person, the likelihood of transferring the aggressiveness while driving is high (Kallberg et al., 1998).

- **Acceptability of present speeds**

It is very important that the speed limits imposed are accepted by all road users. If drivers do not entirely agree with the speed limits imposed, they might not comply with them.

Policy makers are interested in this topic, considering that the success of the policies also relies in some part by their social acceptance (Kallberg et al., 1998).

- **Enforcement**

Enforcement measures can be effective in keeping driving speeds, but this is more effective if the chance of being caught is perceived by the driver as being high (Kallberg et al., 1998). The impact of enforcement of actual speeds depends on several factors (Kallberg et al., 1998):

- The actual speed level compared to speed limit;
- Intensity of enforcement (risk of getting caught);
- Penalty system;
- Publicity.

- **Road design**

Speed reductions can be achieved by isolated physical measures (e.g. speed humps, horizontal deflections and road narrowings, roundabouts, village gateways, pavement treatments and rumble strips) or integrated measures like traffic calming zones in urban areas. Measures that physically restrict driving at high speeds seem most effective, especially speed humps and roundabouts.

A good solution would be to design roads that are “self-explaining”. By designing a road that provides a speed image, that corresponds to the actual speed limit, drivers are more likely to choose the appropriate driving speed almost automatically (Van der Horst, 1998).

- **Behaviour led by differences in vehicles sound-proof construction**

Hearing has great importance in speed estimation (Noguchi, 1990), modern vehicles are gradually becoming more and more sound-proof, which can also be one of the explanations for the tendency to increase speeds.

- **Intelligent Transportation Systems (ITS)**

ITS offer opportunities for providing several forms of feedback to individual drivers, in order to implement variable speed limits to maintain traffic flow and to automate the longitudinal control. The speed limiter and the cruise control are integrated in these type of measures and, therefore, this topic will be further developed.

Chaper 2. Intelligent Transportation Systems

According to the Directive 2010/40/EU (Official Journal of the European Union, 2010), Intelligent Transportation Systems (ITS) are defined as telecommunications, electronics and information technologies that are integrated in transport engineering in order to plan, design, operate, maintain and manage transport systems. The application of those information and communication technologies to the road transport sector and its interfaces with other modes of transport will bring significant contributions: improvement of environmental performance, efficiency (including energy efficiency), safety and security of road transport (including the transport of dangerous goods, public security and passenger and freight mobility), whilst at the same time ensuring the functioning of the internal market as well as increased levels of competitiveness and employment (Official Journal of the European Union, 2010).

ITS can be applied to all transport modes and can facilitate their interlinking. ITS can have very different applications, infrastructure of highways, streets, bridges, tunnels, railways, port and airport infrastructure, as well as to a growing number of vehicles, including cars, buses, trucks and trains, as well as aircraft and waterborne vessels. They also can be applied for both for passenger and freight transport (Sitavancova & Hajek, 2009).

ITS are becoming a constant in the transport context nowadays, and the road context is not an exception. The interest in ITS came mainly from the increasing problems caused by traffic congestion and the contemporaneous opportunity to have a possible synergy between new information technology for simulation, real-time control, and communications networks. Traffic congestion has been increasing worldwide as a result of increased motorisation, urbanisation, population and economy growth, and changes in population density. This causes a reduction in the efficiency of transportation infrastructure and an increase travel time, air pollution, and fuel consumption, which also lead to increased costs (Sitavancova & Hajek, 2009).

Sitavancova and Hajek (2009) mentioned that ITS include transport infrastructure, vehicles and transport/traffic management in an effort to manage factors that typically are at odds with each other, such as vehicles, loads, and routes with the final aim to improve safety and reduce vehicle wear, transportation times, and fuel consumption.

In road context, which is the target context in this study, ITS can be categorized in infrastructure based, vehicle based and cooperative systems (vehicle to road based and/or vehicle to vehicle based). The common background in all of these technologies is the support to the driver and/or the management of traffic in the transport system. On the vehicle side of ITS, there are two major subdivisions that are usually considered: In-vehicle Information and Communication Systems (IVIS) and Advanced Driver Assistance Systems (ADAS).

IVIS and ADAS can, then, be subdivided into intelligent and not intelligent systems. The term ”intelligent” in ITS is used because the system should adapt to the actual situation, anticipate the needs and take initiative and possibly be explanative. In “not intelligent” systems, external factors do not change the way the system works, indeed unlike “intelligent” systems that are regulated by inputs from “outside”, “not intelligent” systems are regulated from inputs that are coming from inside the vehicle, from the driver himself. For the scope of this dissertation only vehicle-based ITS are going to be investigated.

2.1 IVIS (In-vehicle Information and Communication Systems)

In-vehicle Information and Communication Systems make available to drivers several types of information that can be useful to the driving task, like information concerning road conditions, weather broadcast, maps of cities, guidance throughout specific places, vehicle diagnostics and, in some situations, warning systems and emergency help systems. All these equipments, with different functionalities, are used to facilitate and manage the driving task, making it also more efficient and ecological (Adler & Blue, 1998).

IVIS are becoming more and more present in vehicles nowadays. Since people carry around a lot of technological devices with them all the time (laptops, mobile phones, tablets, etc.), it is to be expected that the usage of those objects is also done inside the vehicle, even more considering that, in these days, people can spend a lot of time driving.

IVIS can be used by both private and commercial drivers, for different applications and under different traffic conditions. The appearance of these systems in the market was attributed to the desired optimal use of existing transportation facilities, issue that became a major priority in congested urban areas. Providing alternatives to the crowded roads or even presenting real-time in-vehicle traffic information to drivers, turned out to be one possibility of achieving this goal (Pereira, 2009; Sitavancova & Hajek, 2009).

2.2 ADAS (Advanced Driver Assistance Systems)

According to Linder, Kircher, Vadeby and Nygårdhs (2007), Advanced Driver Assistance Systems are supporting the driver in their primary driving task (safely controlling the vehicle until reaching the destination). They assist the driver and do not take over the driving task completely, thus the responsibility always remains with the driver. They inform and warn the driver, provide feedback on driver actions, increase comfort and reduce the workload by actively stabilizing or manoeuvring the car. With respect to the driving tasks categories (presented further in Chapter 3), ADAS are focusing on the manoeuvring level (PREVENT, 2006).

To summarize, ADAS are characterized by the following properties:

- detect and evaluate the vehicle environment;
- use complex signal processing;
- provide active support for lateral and/or longitudinal control with or without warnings;
- support the driver in the primary driving task.

The speed regulating systems that are investigated in this dissertation, the conventional cruise control and the speed limiter, are included in this category of ITS, mainly because they actively provide support for the longitudinal driving task, taking over the control of speed.

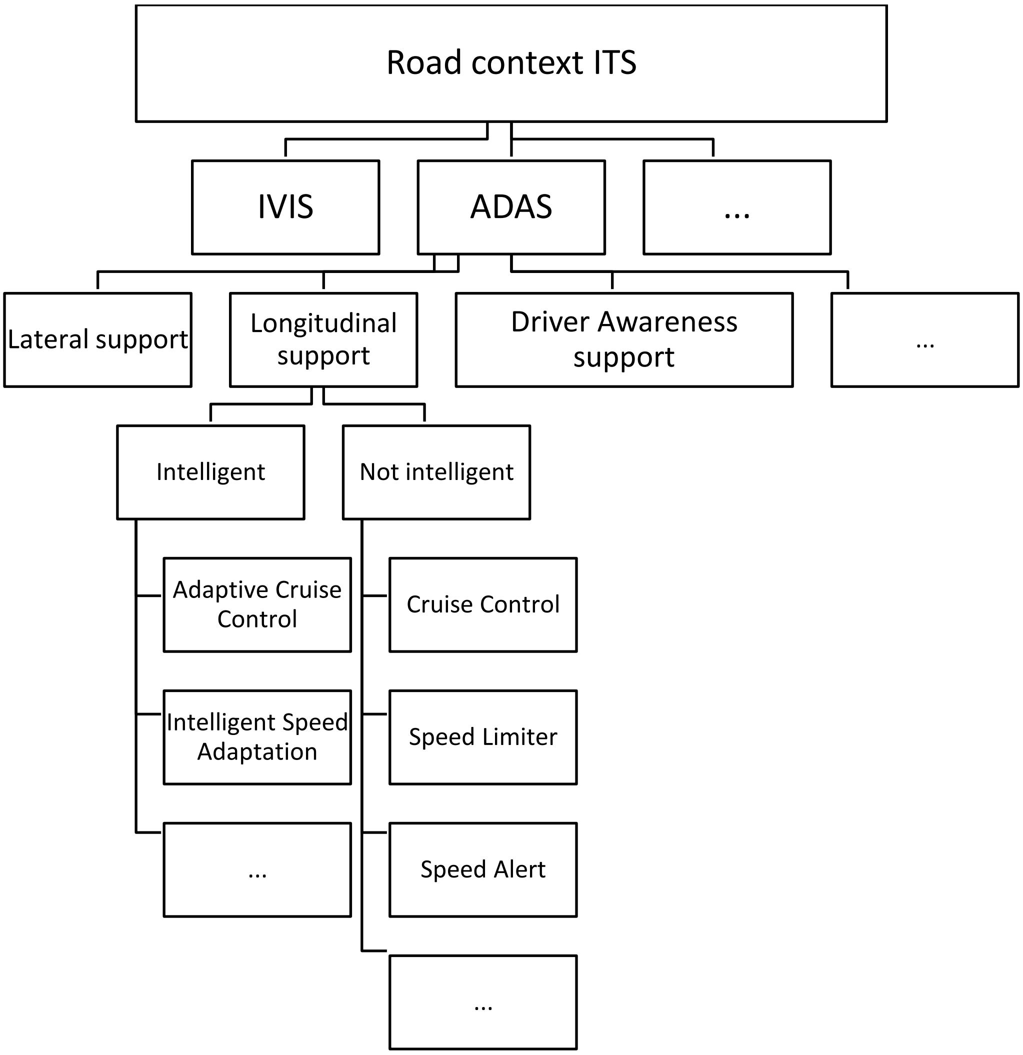

Figure 2. Overview of cruise control and speed limiter in the ITS frame.

2.2.1 Conventional Cruise Control

The conventional cruise control is a driving assistance system whose main aim is to keep a speed predefined by the driver, without the need of the driver to keep pressing the gas pedal (Patterson, 1998).

Different brands have different interfaces for the same system, but there are two main types of instrumentation: in the first one (Figure 3 and Figure 4) there is a lever placed behind the steering wheel, more or less at the same distance from the indicator lever whereas, in the second type of interface, the buttons are placed directly on the steering wheel (Figure 5).

The controls presented in the figures below integrate together the CC and the SL. However, there are also vehicles that include the CC and the SL separately and, some others which only have either the CC, or the SL available.

Figure 3. Mercedes-benz CC/SL systems' lever.

Figure 4. Peugeot CC/SL systems' lever.

Figure 5. Renault CC/SL systems' buttons.

In interfaces that have both systems available, there are 2 distinct steps in the use. The driver, at first, chooses which one of the systems he/she wants to use and, then, he/she can activate/deactivate the system.

In the first moment, the driver has to turn the lever or switch (this depends on the vehicle make and model) to the CC side, and the system is on. The speed can appear on the display but that doesn't mean that the vehicle speed is already being maintained by the system. In the second moment, when the system is already on, there is usually a sequence of steps that are taken by the driver and that can be split in two separate phases: the setting of the desired speed and the system deactivation. The former can be done by accelerating the vehicle until it reaches the desired speed and, then, pressing the set button or by pressing the "+" or "-" button until the desired speed is reached. The increment of speed is done either 1 km/h by 1 km/h or 2 km/h by 2 km/h (also depending on the brand and model of the vehicle).

When a speed is chosen, it stays in the system's memory, so the driver can recall it, after deactivating the system, by pressing the "Resume" button (it appears on the controls as an "R"). The deactivation of the speed can either be done applying some pressure on the brake pedal or even pressing the "Cancel" button. It must be noted that pressing the accelerator does not alter the set speed. Consequently, when the accelerator pedal is released, the vehicle returns to the previous settings (Rakha, Hankey, Patterson, &Van Aerde, 2001).

Pressing the "Off" button or turning off the ignition turns the CC system off and erases the memory.

Conventional cruise control takes over the accelerator operation only at speeds over 40 km/h, when it is engaged (Rakha et al., 2001).

2.2.2 Speed Limiter

The speed limiter consists of an active gas pedal that provides a counter-force, perceived by the feet of the driver, whenever the driver tries to exceed the pre-set speed limit.

When the driver wants to use the SL, he has to turn the lever or switch (this will depend on the vehicle brand and model) to the SL, and the system is on. In a second moment, the speed can be set: this operation can be done by accelerating the vehicle until it reaches the desired speed and pressing the set button or by pressing the "+" or "-" button until when the desired speed is reached. The increment of speed is also done like the CC, either 1 km/h by 1 km/h or 2 km/h by 2 km/h (also depending on the make and model of the vehicle).

When the driver doesn't want to use the system anymore, he/she just needs to switch the lever or switch to the "Off" position.

The pedal resistance is sufficient to remind drivers of the speed limit, and the extra effort required to go faster is sufficient to deter them from speeding. The performance of the vehicle is not affected by the system at speed values below the pre-set level. When the speed of the vehicle approaches the pre-set limit, the counter-force of the accelerator gradually increases. However, the engine's fuel injection is restricted when the vehicle reaches the pre-set speed limit. In order not to cut the acceleration abruptly, and to have a smooth transition to the limited mode, the device allows the speed to exceed the limit initially but then, the accelerator cannot be depressed until the speed of the car decreases below the pre-set speed limit.

However, if the driver depresses the clutch pedal when driving downhill, then the car can overcome the pre-set speed limit by rolling freely (Várhelyi & Mäkinen, 2001).

Chapter 3. Driving task and drivers' activity

Driving is frequently thought as a perceptual-motor task, in which all that is required is driver's manipulation on the car controls at the same time that he/she tracks various changes in the environment. This view might lead to considering that driving is a relatively simple task but, actually, there are a lot of constraints when the task is being performed: driving relies on complex human sub-tasks that must be performed together in order to achieve what it might seem like trivial driving tasks (Groeger, 2000). To deal with the complexity and to better study the driving task, researchers suggested models that decompose it in different levels.

In 1979, Michon (as cited in Bellet, Tattegrain-Veste, Chapon, Bruyas, Pachiaudi, Deleurence, & Guilhon., 2003) proposed a hierarchical model to classify the driving task (Figure 6). In this model, the highest level is the strategic (or planning) level, below there is the tactical (or maneuvering) level, and finally the control (or operational) level.

The *strategic level* is related with the purpose of the trip and the driver's goals. It consists of all processes concerning trip decisions, such as general trip planning, vehicle selection, route selection (and other navigational considerations), setting trip goals, trip safety considerations etc. The strategic decision making hardly requires any new/environmental information, it is largely memory driven. Time management is also taken into account at this level: the time to start the trip, its duration and the destination that should be reached. In addition, decisions can take several minutes to be taken.

The *tactical level* is associated with the choice of maneuvers and immediate goals that the drivers' faces when trying to reach the destination. This involves dealing with common driving situations like gap acceptance, speed selection, overtaking decisions, obstacle avoidance, lane choice, etc. At this level, the behavior is influenced by both situational and motivational variables. *Tactical level* decisions are considered to take place in seconds.

The *operational level* corresponds to the way the drivers perform the actions, and the way he/she manipulates the vehicle controls. If the driver decides to reduce his/her speed (tactical level), then he/she can act in distinct ways: simply remove the foot from the accelerator, remove the foot from the accelerator and press the brake or press the brake and reducing the gear at the same time. To fulfill the same tactical goal, the driver can choose to perform different actions. Compared to the previous ones, at this level, decisions are taken instantly. These three levels are happening simultaneously and interfere with one another. But yet, the level of information needed at each level is not the same (Groeger, 1999).

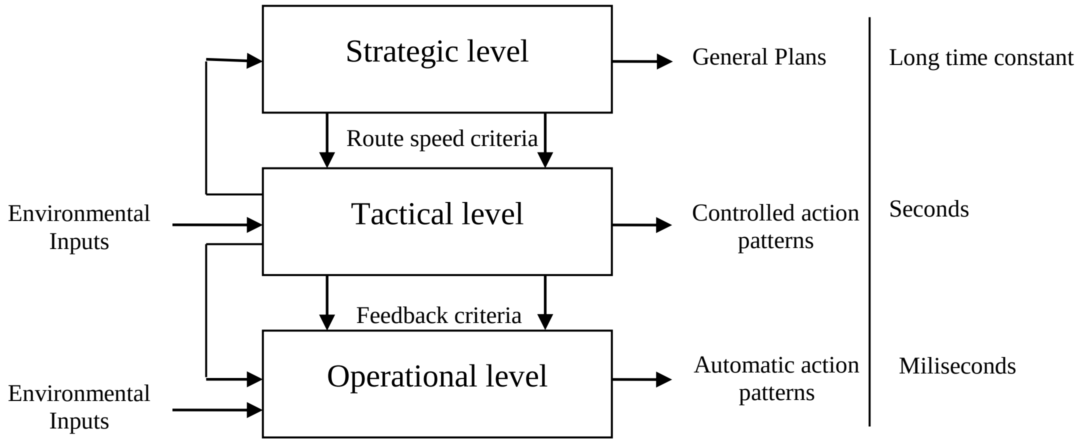

Figure 6. The hierarchical structure of the road user task (Michon, 1985).

In 1987, Rasmussen (as cited in Groeger, 1999) defined three different levels that explain the human behaviour while perform the driving activity: the skill-based level (SB), the rule-based level (RB) and the knowledge-based level (KB). The *skill-based level* is where the automatic control of routine tasks takes place. Actions like the control of the speed and the lateral control of the vehicle can be performed in this stage once they are frequently performed automatically, at least for experienced drivers. This is the level where the motor and sensory automatisms are activated and actions are performed without conscious knowledge, except for occasional checks on the progress of the driving activity.

In the *rule-based level* of performance, activity is based on routines and relies on signs, controlled rules and procedures learned from previous experience. These procedures can also be acquired through transference of experience from others; through formal learning or even elaborated by past problem solving techniques acquired by the individual. For instance, situations like how drivers should react to other vehicles are clearly specified in highway codes and road traffic laws and control driver performance in many ways.

Compared to the previous two levels, k*nowledge-based* behaviours are activated when no obvious familiar solution appears adequate in solving the problem in hand. When an unusual situation occurs and there is no specific rule to apply, the driver's knowledge has to be "activated" in order to solve the dilemma. At this level, the subject consciously mobilizes his/her resources to face the problem to accomplish that specific objective.

These three levels of the task performance can coexist at the same time, which is evident in the driving task: the control of speed and direction is performed at the SB level, while the interaction with other drivers and pedestrians is carried out at the RB level; simultaneously, a problem may occur imposing its resolution at the KB level. Being the SB and RB levels faster, less effortful and almost unlimited in capacity, the individual's available resources to process information could be saturated when solving a particular problem or performing an additional task. The information processing will then involve the three control modes (SB, RB and KB) simultaneously, imposing a mental overload to the individual, which can lead to critical situations (Figure 7). This hierarchical control structure is useful to explain typical categories of errors that are considered as occurrences of mismatches in human-machine interactions in dynamic environments.

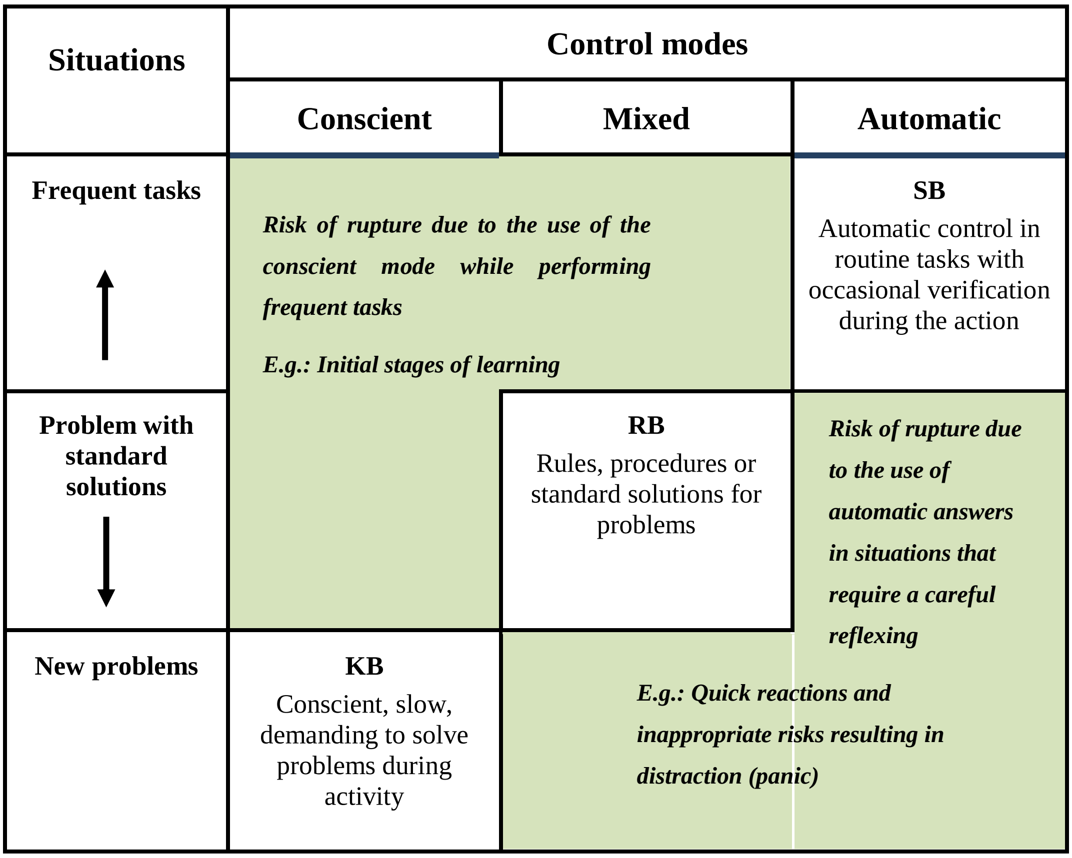

Figure 7. Three levels of task performance (Rasmussen, 1996).

Chapter 4. Drivers' information processing

The human information processing model in Figure 8, it is a more recent model proposed by Wickens (2004) that provides a systemic view over how the information is processed by humans. The stages in which humans process the information help us to understand how functions are linked to transform or carry out some other operation on the information. This model also helps to have a better and more global idea from where the concepts that are going to be defined ahead fit in the information processing.

We can see from the model that attentional resources are present in the 3 main stages of the information process (perceptual encoding, central processing and in the response). This means that attention is important for *stimuli* perception, decision making, response selection and execution. When something is perceived, it can lead directly to a response selection and execution (typical procedure in automated tasks) or it might be required to process the perceived information in the working memory to select a response. The working memory is a type of memory with a limited storage capacity, which works with information stored in the long-term memory, the information is activated and retrieved (knowledge) and compared to the environment information to make a decision, that decision is based on the mental representation of the current situation. The long-term memory has unlimited storage capacity and it is a reservoir of data structures representing concepts, schemas and operative knowledge. The presence of the feedback loop at the bottom of the model suggests that there is no fixed starting point in the sequence of the processed informations and that the responses are used also as inputs for the information processing model.

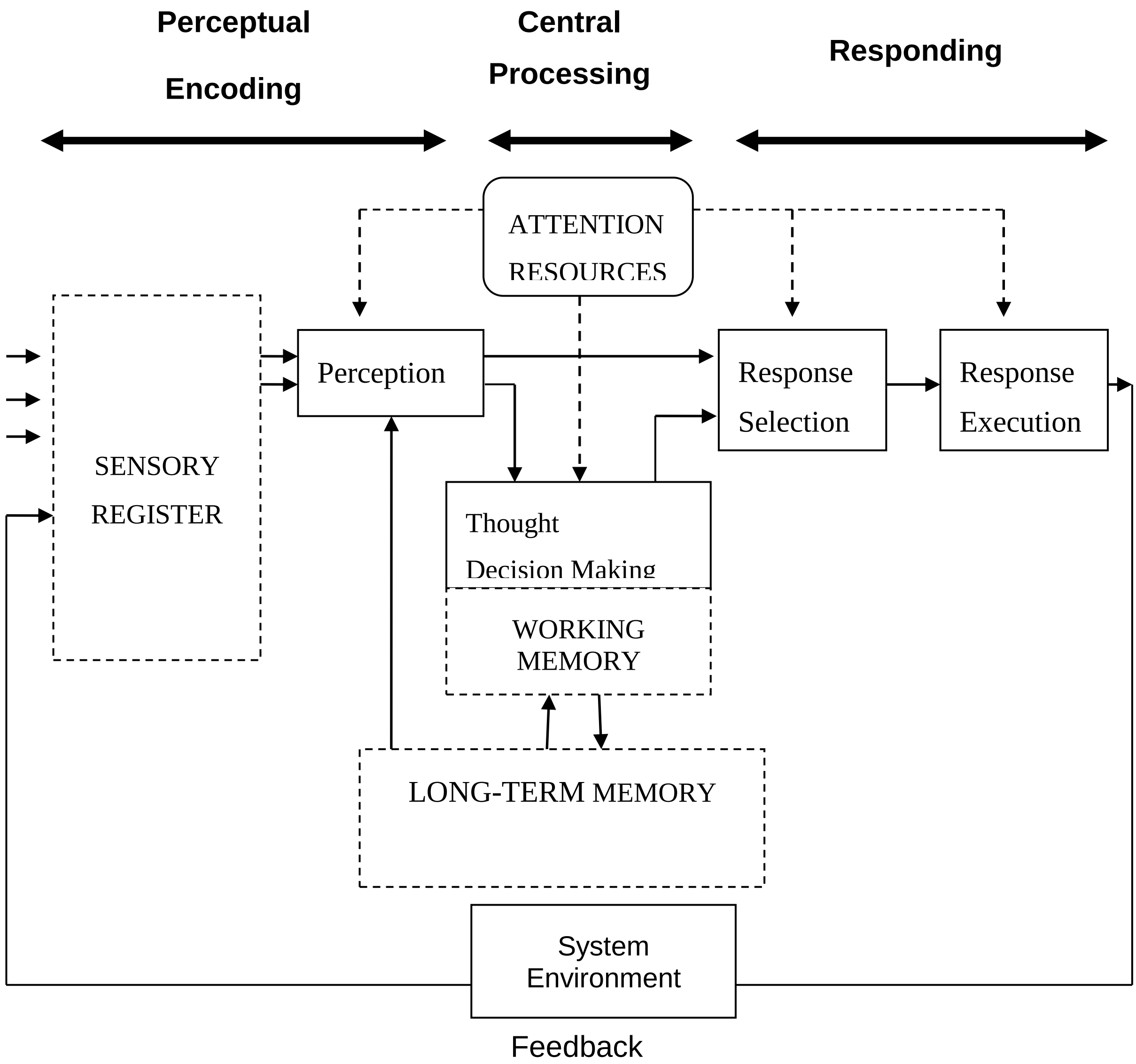

Figure 8. Model of Human information processing stages (Wickens, 2004).

4.1 Attention

After a brief description about how humans process information, it is important to give an overview about the models used over the years to define attention. The next two models presented in this section are the main ones to explain how attention operates and give different perspectives. The Spotlight model was used over many years of research in visual attention to generate new questions and findings. The idea of a spotlight as a metaphor for visual attention was suggested by Posner, Snyder, & Davidson (1980), although the concept may have originated before. In this model, it is stated that everything within a fairly small region of the visual field can be seen clearly and it's harder to see anything that is not within the beam of the attentional spotlight (Eysenck & Kean, 2005).

The other model discussed here is the Attentional zoom lens model**,** proposed by Eriksen and St. James in 1986, compares attention to a searchlight, ranging over a scene and whose diameter of the beam can be varied from narrow to wide:

- High power (narrow) setting- the attentional resources are concentrated on a very small part of the visual field to extract very detailed information;
- Low power (wide) setting- there is an even distribution of the attentional resources over the effective visual field, but little discrimination of detail.

This model suggests that as the size of the attentional field increases, the density of processing resources within that field decreases (Eriksen & St. James, 1986).

There are two main determinants of where attention is directed to: exogenous and endogenous factors (Egeth & Yantis, 1997). Attention can be captured automatically and involuntarily by environmental stimuli, (normally conspicuous stimuli) called exogenous factors. We call **bottom-up control** when attention is caught by exogenous cues such as sudden movement or appearance of a new object. For example, if a very colored car appears suddenly, it's hard not to notice it. On the other hand attention can also be driven by goals, and in this case we are talking about **top-down control** of attention, meaning that your attention can be directed to something in a voluntary and conscious way (endogenous factors). For example, when a driver is already expecting a particular event and his/her resources are focused on that, he/she might miss or process later other abrupt events. It is now considered that these two attentional systems interact with each other.

Attention can also be divided in two different categories in terms of amount of processed inputs, selective and divided attention, as it can be seen on the figure 11.

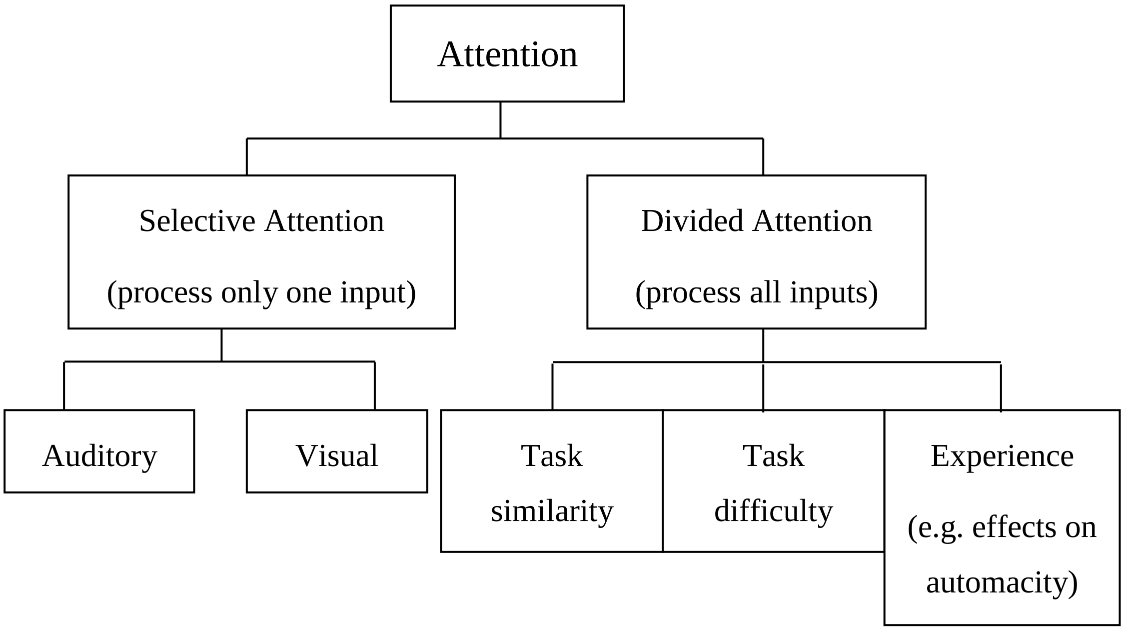

Figure 9. Types of attention (Eysenck & Kean, 2005).

4.1.1 Divided attention

We speak about divided attention when a person tries to process more than one input at the same time: this usually happens when someone is performing more than one task (e.g. when a driver engages into phone conversation while driving). If the tasks carried out are too similar, the performance will decrease, like in the case of driving a car and watching the television (both tasks have high visual demands). The ability to perform more than one task at the same time also depends on the difficulty of those tasks: for instance, if the task is automated, it is more likely that the human would be able to perform others tasks at the same time (since less attentional resources are spent on the automated task). For example, for someone that has just got the driver license it's difficult to perform other tasks while driving; however, if the driving task was automated, it would be easier to engage in other activities at the same time.

In 2002, Wickens proposed the multiple resource model with four dimensions that account for time sharing in performance. This model helps us to understand better some behaviours that drivers might adopt in terms of secondary tasks. The four dimensions, presented in Figure 10, are: processing *stages*, perceptual *modalities*, visual *channels*, and processing *codes*. Each dimension has two 'levels' that are going to be presented below.

In the processing stage of performance, there are 3 levels: perception, cognition or responding. The resources used for perceptual activities and for cognitive activities appear to be the same, and functionally, they are separated from the ones underlying the selection and execution of responses (Wickens, 2002).

The perceptual modalities that are considered are the visual and the auditory: is easier for humans to divide attention between two tasks, one visual and other auditory, than between two visual or two auditory tasks (Wickens, 2002).

Concerning visual processing, there are two aspects the focal and ambient vision that are referred to as the visual channels. These two visual channels appear to define separate resources. Focal vision is required for fine detail and pattern recognition (e.g. recognizing a hazardous object in the middle of the road). Ambient vision involves mostly peripheral vision and it is used for sensing orientation and motion, the direction and speed with which one moves through the environment (e.g. driving the car inside the road marks) (Wickens, 2002).

Processing codes is the dimension that distinguishes spatial from verbal processes. The separation of spatial and verbal resources seemingly accounts for the relatively high degree of efficiency with which manual and vocal responses can be time-shared, assuming that manual responses are usually spatial in nature (tracking, steering) and vocal ones are usually verbal (speaking).

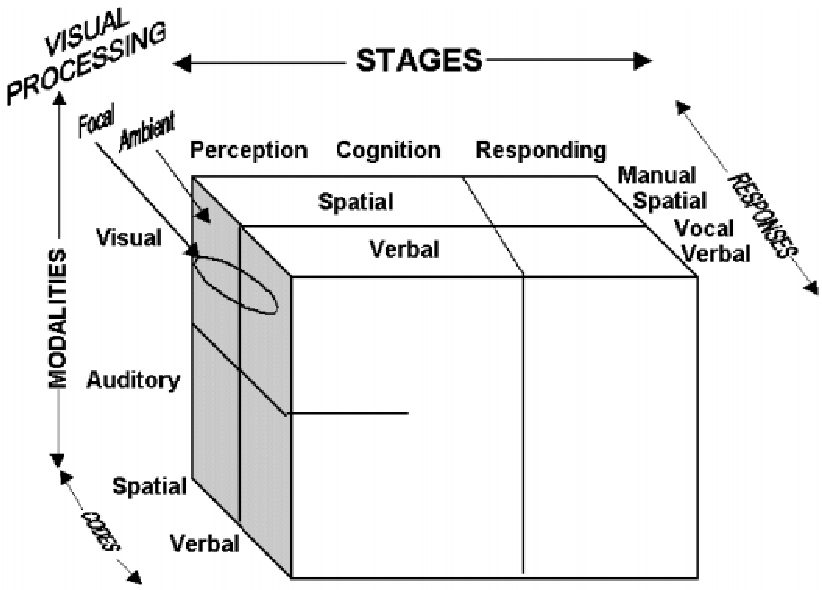

Figure 10. Multiple resource theory three-dimensional diagram structure (Wickens, 2002).

4.1.2 Selective attention

One important function of attention is to enable us to select certain information for processing. Selective attention involves filtering stimulus information and it can be defined as the ability to ignore irrelevant stimuli while focusing attention on relevant ones (Parasuraman as cited in Eby, Trombley, Molnar, & Shope, 1998). Attention switching happens when people quickly shift their attention among important stimuli. In order to drive effectively, subjects have to be able to ignore irrelevant inputs and focus attention on vehicle control and movements of nearby vehicles. Visual selective attention can be either space-based or object based: in space-based selective attention, objects that fall within the focus of attention are more effectively processed than objects that fall outside of the attentional window, in the margin (like the spotlight and the zoom lens metaphors presented before, implying that visual attention corresponds to a focus or a margin). Theories that have used these three conceptualizations of attention are referred to as space-based theories and they posit that attention is directed to a spatially defined region of an image. On the other hand, more recent research emphasizes that attention can be used to select objects and perceptual groups and therefore, that visual attention is object-based. According to object-based theories of selective attention, attention selects preattentively (unconscious process that is, basically, the accumulation of available information) defined perceptual objects based on the Gestalt principles such as proximity, similarity and common motion. Kahneman, Treisman, & Gibbs (1992) proposed that the visual field is preattentively segregated into perceptual objects and, then, focused attention selects specific objects for more detailed analysis.

4.1 Situation Awareness

Human's information processing is a very dynamic process and Situation Awareness (SA) is a very important state that represents how drivers interact with the information that is available on the environment that surrounds them.

SA is defined as 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, 1995), as it can be seen on the figure below. SA plays a vital role in driving, as in every dynamic decision making environment.

The three level model suggested by Endsley describes SA as a state of knowledge or product that is separated from the process used to achieve it: in other words, SA is separated from decision making and performance, but there is a link between SA and working memory, attention, workload and stress.

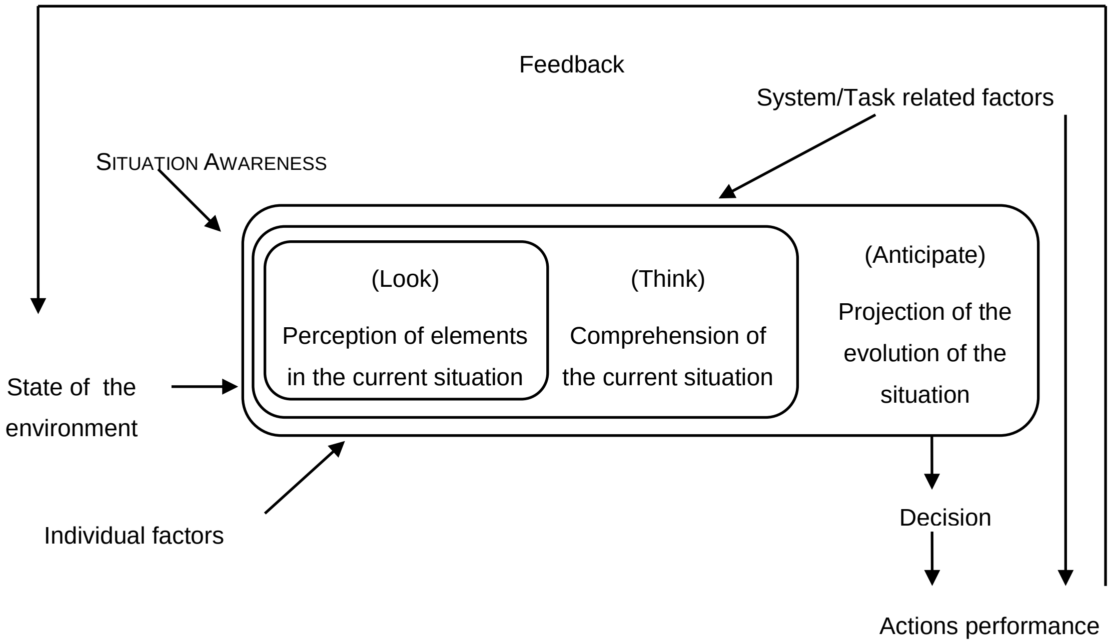

Figure 11. Model of Situation Awareness in driving (Endsley, 1999).

Attention plays an important role in the first level of SA, the perception of the elements of the situation. The following conditions related to the three levels of situation awareness and can explain some inappropriate drivers' behaviour (Endsley, 1999):

1. Misperception: Lack of or hidden information in the environment, lack of attention, visual difficulties (Visual acuity – static and dynamic – or reduced useful field of view), and confusion in a complex road environment (too much information resulting in difficulties in selecting the relevant information);

2. Incorrect interpretation of the situation (inexperience, confusion resulting from too much information to be processed in useful time or insufficient knowledge);

3. Inappropriate decision resulting directly from an incorrect projection of the situation due to one or both previous phases (perception or interpretation of the situation).

Chapter 5. Automation and behavioural adaptation

Automation happens when a machine assumes a task that was, previously, performed by a human operator (Wickens, 2004). Automation has the potential to bring many benefits to the human activity being, one of those benefits the improvement in efficiency. Modern technological systems are shifting the operator's task from the physical level to cognitive level. When a task is automated, the operator's role is qualitatively changed, and this introduces new concerns and issues (Stanton & Marsden, 1996). Among the possible concerns, negative behavioural adaptations might occur when humans deal with automated systems. OECD (1990) defined behavioural adaptation as "those behaviors which may occur following the introduction of changes to the road–vehicle–user system and which were not intended by the initiators of the change". The CC and the SL are systems that automate some parts of the driving task as it was already explained above; their introduction is, therefore, a potential cause for drivers' behavioural adaptations.

Another problem associated with automation is mental workload. One of the purposes of automation is to reduce mental workload, and, consequently, improving performance, considering that if decreasing human activity an operator is overloaded, his performance is likely to become worse. However, automated systems have the potential for imposing mental underload which can be as detrimental to performance as overload (Desmond & Hoyes, 1996). When underloaded, a driver might feel compelled to compensate the reduction of workload by engaging into others tasks such as secondary distracting activities. In this case, distraction can be seen as another behavioural adaptation to automation (see Hockey, 1997).

Drivers' limited attention combined with an highly passive monitory task and consequently decreasing vigilance levels can results in a poor SA, and this can represent safety concerns for the driver.

When the human role changes to the point that he is required to perform almost no action and just monitor the machine performing, we can also talk about fatigue. Usually we associate fatigue to activities that require several interventions of the operator in a small period of time but the opposite situation is also causing fatigue.

The topics presented below represent the main issues related to automation which is relevant to evaluate when studying speed regulating systems use (CC and SL in particular). The other concerns (e.g. overtrust) will not be treated for the aim of this particular study.

5.1 Mental Workload

The concept of human mental workload can be traced back several decades ago in the frame of human-machine systems in the transportation field. There are some approaches (e.g. Hart & Wickens, 1990) defining the concept of mental workload based on the relation between the environmental demands imposed on the human operator and the capabilities of the operator to meet those demands. However, these approaches can be quite static and they don't take into account other important human characteristics.

With a different approach, Parasuraman and Hancock (2001) believe that workload can also be mediated by the human response to load, to personal skill levels, task management strategies, and other personal characteristics.

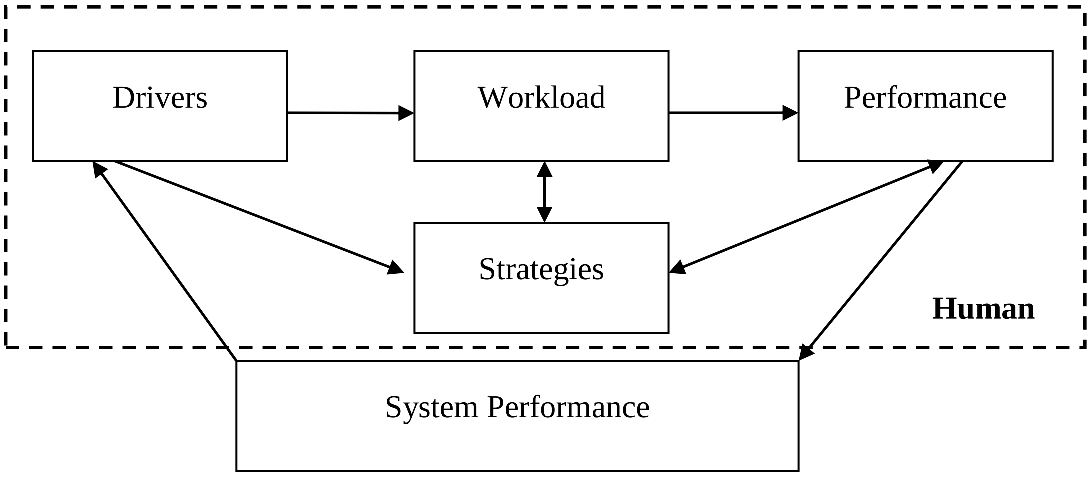

Figure 12. Inter-relationships between workload drivers, workload and performance (Parasuraman & Hancock, 2001) (p.307).

"Drivers" (concept presented on the figure above) are factors that guide workload, being these factors can be external (coming from the environment) or internal (skill or motivation). To deal with the "drivers" and workload while performing an action, the operator starts developing strategies: the more experienced is the operator, the more strategies he can adapt. Finally the human performance is the result of the interaction between the "drivers" on workload and the strategies that are used to cope with workload. The human performance will be the input for the system performance and the system performance will influence the drivers. It is very hard to determine how workload increases and decreases because humans are very effective when it they need to develop strategies to cope with the demand: for this reason, it is not always observable the association between task load and mental workload (Parasuraman & Hancock, 2001).

Another approach is defined by Hockey (1997), who developed the compensatory control model, which explains how human operators regulate their performance level at any driving task. The model distinguishes 2 types of levels of control, the first associated with routine regulation and the second with effort-based regulation. The first loop is dealing with keeping the performance level according to the defined goals whereas the second loop monitors the workload involved in achieving the level performance. According to this theory, when the workload achieves a high level (that differs from person to person), the goals can be adapted and a lower level of performance can be accepted by the operator to cope with the given constraints. The opposite is also true: when the workload achieves a low level, the goals can be adapted to increase the workload to an optimum level. Since ADAS reduce drivers workload by automating some of the drivers previous tasks we can think that a driver could accept engaging into secondary tasks as a way to increase his workload to that optimum level.

5.2 Distraction

Distraction has been the target of many definitions along time, as a consequence of the impact that this concept has been winning over the years, due to the evolution of the driving context (e.g. more complex driving contexts and more information available on the roads) and the evolution of the vehicles that are equipped with more technological systems (e.g. Intelligent Transportation Systems). Some of the definitions of distraction are reported below.

Beirness, Simpson and Desmond (2002) emphasize the need to distinguish inattention from distraction, considering distracted driving as a part of the broader category of driver inattention: the presence of a triggering event or activity distinguishes driver distraction as a subcategory of driver inattention.

Smiley (2005) describes distraction as “misallocated attention”, stating that the extent of misallocated attention depends on the driver state, the driving task and the driving environment. She claims that the major reason causing distraction is the fact that humans are “serial, limited capacity processors of information”, who at times do not prioritize well. This is a broader definition of distraction, that includes the concept of being “lost in thought”, and, as well, self-initiated secondary tasks. She also considers driving tasks, like looking in the mirror, that are executed in an inappropriate moment. Hedlund, Simpson, & Mayhew (2006) published this definition of distraction that has been agreed during the First International Conference on Distracted Driving in 2005:

Distraction involves a diversion of attention from driving, because the driver is temporarily focusing on an object, person, task, or event not related to driving, which reduces the driver’s awareness, decision-making, and/or performance, leading to an increased risk of corrective actions, near-crashes, or crashes.

In the context of this thesis, the concept of distraction is relevant because if the driver is underloaded while using speed regulating systems, it is possible that he/she will try to engage in other activities (physical or cognitive), which might distract him.

5.3 Poor SA

To maintain an appropriate level of SA while driving is already a challenge for the driver so that the introduction of automation might further worsen the human’s ability to build a SA adequate to the task. Automation, in general, can have a detrimental impact in SA, and those impacts can be the following (Endsley, Bolté and Jones, 2003): (1) out-of-the–loop syndrome - when automation reduces drivers’ ability to detect systems’ failures or problems and to understand the state of the system sufficiently to allow them to take over operations manually; (2) automation understanding problem - when the operators frequently misunderstand what the system is doing and why is doing it which is necessary to comprehend and build a projection of the situation (Levels 2 and 3 from SA); (3) decision support dilemma- caused by tendency of decision-aiding automation to interact with attention and information evaluation processes in such a way as to diminish their intended effectiveness. The out-of-the-loop syndrome is the most relevant issue to focus on because, when automation fails or an unexpected situation happens, the operator (in this case the driver) has to be able to detect the problem and take over the task manually.

The loss of SA can result in some delay in taking over manual performance, leading to extremely problematic situations such as an accident.

The loss of SA occurs through three primary mechanisms (Endsley & Kiris, 1995):

1. Changes in vigilance and complacency associated with monitoring;
2. Assumption of a passive role instead of an active role in processing information for controlling the system;
3. Changes in the quality or form of feedback provided to the human operator.

As an example of loss of SA during the driving assisted with cruise control, it is possible to think to the following situation: a person has been driving in the highway with the cruise control activated for the last hour. Suddenly the car traveling on the left lane, moves to the right lane, in front of the vehicle equipped with cruise control. In this context, if the driver is not vigilant enough, an accident might occur due to the high amount of time taken by the driver to react to the new situation. In this case, the absence of relevant events during the driving with the cruise control activated, might deteriorate the SA of the driver and, this conflict situation might end up in an accident, due to the excessive time spent by the driver to take again the control of the vehicle. This loss of SA is also related with mental workload model, above presented (and, notably, this is an example of driver's underload).

5.4 Fatigue

Fatigue is one of the critical concerns to be considered during the performance of a task; in transportation, fatigue is particularly important, since, sometimes, it is the cause of accidents.

The concept of fatigue has been hard to define through the years because it is a multidimensional state that can only be perceived by the individual that is experiencing it (Desmond & Hancock, 2001). Fatigue is the consequence of several factors, and, among them, information rate (the temporal frequency of information assimilation) and information structure (the spatial variation of information presentation) are considered the main ones. These factors are related to characteristics of the environmental stimulation but also are inextricably linked to the endogenous characteristics of the performer (Desmond & Hancock, 2001).

It is possible to distinguish two different forms of fatigue based on their different causes: active and passive fatigue. Active fatigue is caused by continuous and prolonged, task-related perceptual motor adjustment: in this situation, fatigue is associated with overstimulation. On the other hand passive fatigue is caused by the lower monitoring requirements or even no evident perceptual-motor response requirements: in this last case, fatigue is related to understimulation (Desmond & Hancock, 2001). Passive fatigue is usually associated with automated systems, when the operators' role is mainly to monitor and he/she rarely needs to take action to control that system. It seems that passive fatigue that emerges from monitoring a system for a prolonged period is as stressful and tiring as continued performance of the same task and may result in more detrimental after effects (Desmond & Hancock, 2001).

Chapter 6. Drivers' variability

6.1 Age and driving

With respect to age, young and older drivers are the two age groups which deserve more attention for what concerns road safety. Even though these two groups have different characteristics (e.g., lifestyle, habits, etc.), they share one negative feature related to the driving task, that is the high rates of fatalities (Figure 13).

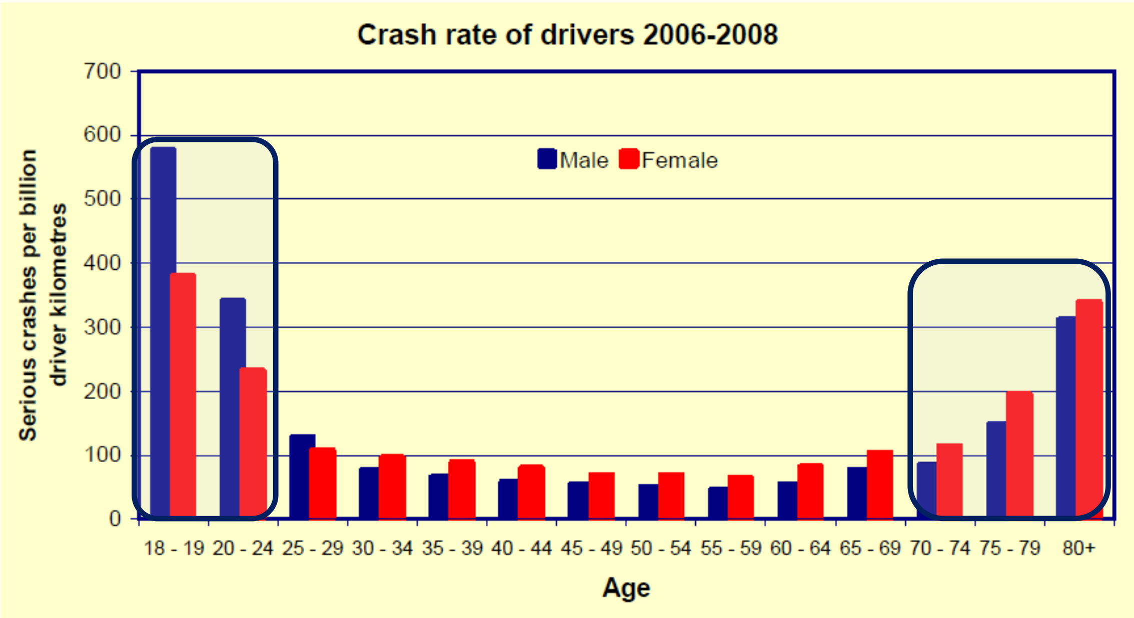

Figure 13. Number of crashes with fatalities or in-patients per billion driven kilometers for age groups (2006-2008) (SWOV, 2010).

The characteristics of both groups (young and older drivers) will be further presented in the next sections.

6.1.1 Young Drivers

Young drivers (18-24 years old) have a high risk of being involved in a serious road crash (with at least one fatality or in-patient): their risk is more than four times higher compared to the drivers in the age range 30-59 years old (OECD, 2006).

The fact of being young is always related to the fact of being a novice for what concerns driving and, sometimes, the two concepts are not clearly distinguished when speaking about road safety. However, the crash involvement of novice drivers decreases as the driving licensing age increases, indicating that the age factor plays a central role in causing crashes: physical and emotional immaturity, as well as the lifestyles associated with youth can increase crash risk and severity. For example, young people’s life is often intensely social, usually driving at night and on weekends, in groups, and sometimes, after consuming alcohol and/or drugs (OCDE, 2006). The experience is crucial to acquire competence in driving: with experience, actions like changing gears, looking in the rear-view mirror, steering, correctly assessing situations and reacting appropriately to critical situations become automated. Being the novice driver new to the driving task, these actions require consideration, increasing overall mental workload and possibly distracting attention from the road. Thus, novice drivers’ attention is easily overloaded, and their ability to combine simultaneous actions is relatively poor. At the same time, since serious crashes are relatively rare events, new drivers are not provided with the sort of negative feedback that might induce them to drive more carefully. In addition, they might keep a unsafe behaviour being motivated to arrive at a destination as quickly as possible, or by other factors, such as peer pressure or a desire to “show off” (OCDE, 2006).

Regarding gender, young men drive more than young women, and have more fatal crashes per kilometer driven. This negative performance might be caused by the fact that young males are more prone to risk-taking, sensation-seeking, speeding, rule-breaking behaviour and more likely to over-estimate their driving abilities (OCDE, 2006) compared to their female counterparts.

6.1.2 Elderly Drivers

According to a European Commission’s report, senior citizens aged over 65 years will represent the 20.4% of the European population in 2020 (European Commission, 2011). This ageing trend has a strong global impact on economy, finance and healthcare of all the countries being part of the EU. Furthermore, it also deeply affects the mobility of the EU: being people more long-lived, they are also driving later and travelling more miles than before. Elderly drivers, as other drivers, depend on the automobile for their daily life in order to perform activities such as shopping, going to work and social life. However, there are some factors which might induce the elderly to take the decision of reducing or, in the worst scenario, giving up driving, like the functional declines caused by age. The ageing process and the natural functional declines change drivers' ability and it is possible to observe impairments at sensory-motor or cognitive levels (Eby et al., 1998). The most common natural functional declines that accompany the ageing process and that might affect the driving performance are:

- a decline in various visual capabilities such as acuity of vision, peripheral vision, perception of depth and motion, and contrast sensitivity;
- a decline in the capacity to distinguish relevant from irrelevant information (selective attention);
- a decline in the capacity to divide attention between several tasks (divided attention);
- a slower perception-reaction time;
- reduced flexibility of neck and torso;
- a decrease in muscle strength;
- slowing of the movements;
- a decrease of fine motor coordination;
- reduced capability to adapt to sudden changes of bodily position (SWOV, 2008).

Notably, some complex driving situations that demand a rapid series of decisions can be particularly problematic for some elderly once it was already reported that cognitive deficits can be linked to safety (McKnight & McKnight, 1999). Findings suggest that elderly drivers may not be able to distribute their attention to different stimuli at once as well as younger drivers can, at least not when some of those stimuli are at the center of their visual field and others are in the periphery (Ball, Roenker,& Bruni, 1990). Ball et al. (1990) established the contribution of three attention factors as bases for age-related reduction in the UFOV: reduced speed of visual processing, reduced ability to divide attention and reduced salience of the target against its background.

Even though older drivers might have age related declines, they usually develop strategies to cope with those limitations, especially because those declines are gradual in time. Hakamies-Blomqvist (1994) speculated that older drivers might engage in a more serial organization of vehicle-control operations, probably in order to reduce processing demands. In addition, cognitive slowing can be compensated at tactical level by driving slower and defensively (Hole, 2007).

Evans (1988) reported that elderly drivers have fewer accidents and commit fewer traffic offences than younger drivers. Apparently, older drivers are safer drivers when compared with younger drivers but we have to take into consideration that most of the studies carried out, don't take into consideration these group risk exposure, since younger drivers usually drive more than older drivers and do it more during the night period. This could mean that older drivers' accident risk might be underestimated. It seems that on the contrary of common saying, there are few evidences relating the increase of age with poor driving. Also, few relationships have been found between declines in single functions, poor driving performance and crash risk (ERSO, 2006).

6.2 Gender and driving behaviour

Usually, in studies that concern ADAS, gender is not considered as independent variable because differences between males and females are not significant enough. However, in terms of driving behaviour, the differences are very clear: for this reason, it might be interesting to investigate how those differences affect the way is which drivers interact with the systems. Among the various reasons that explain the gender differences in risk taking behaviour while driving, the following ones will be taken into account: aggressive driving, speeding and violation of traffic laws and sensation seeking and risk-taking (Social Issues Research Center, 2004).

6.2.1 Aggressive driving

In 2012, the National Highway Traffic Safety Administration (NHTSA) defined aggressive driving as "when individuals commit a combination of moving traffic offenses so as to endanger other persons or property." Some other working groups define aggressive driving as "the operation of a motor vehicle involving three or more moving violations as part of a single continuous sequence of driving acts, which is likely to endanger any person or property."

Several studies show evidence that men, particularly young men, tend to be more aggressive than women (in all known cultures) and express that aggression in a direct, rather than indirect, manner. This has a very significant impact on driving – encouraging more competitive and hostile behaviour with consequent higher probabilities of crashing (SIRC, 2004). Women reported fewer behaviors of this aggressive driving when compared to men (Lajunen & Parker, 2001).

6.2.2 Speeding and violations of traffic laws

Norris, Mathews, & Riad (2000) reported that females were significantly less involved than males in accidents caused by speeding and by veering off road lanes. They also noted that a proportion of the higher accident rates for male drivers could be explained by their greater tendency to disregard speed limits and other traffic rules. Likely, Yagil (1998) conducted a study among university students whose results indicate that females had a stronger sense of obligation to respect traffic laws. Females were also more likely to evaluate traffic laws positively. The observed gender differences were particularly pronounced among young drivers, being young males particularly more likely to evaluate traffic laws negatively and to underestimate the risks associated with traffic violations.

6.2.3 Sensation-seeking and risk-taking

Zuckerman (1979) defined-sensation seeking as a personality trait believed to have a biological basis and which can be expressed as a need for physiological arousal, novel experience, and a willingness to take social, physical, and financial risks to obtain such arousal. Previous studies clearly demonstrate broad gender differences in risk-taking and sensation-seeking behaviours. Most studies show that men engage in dangerous activities far more frequently than women and that these tendencies are spread across a wide range of behaviors, including driving (SIRC, 2004). The gender difference might be explained partly with variations in levels of testosterone (in interaction with other hormones and neurochemical changes) and also by the great differences in average testosterone levels between genders (SIRC, 2004).

Chapter 7. Research Questions

ADAS are developed with the aim of reducing the mental workload of the driver, this means that these systems should make the driving task easier physically or mentally, using the warnings or the automatic control of some sub-task in terms of driving. Being that the CC and the SL belong to this category of systems, it is expected that they will change the driving task.

The aim of the present research was to identify driver's perceptions about the effects of the cruise control and the speed limiter in the driving task. Thus, in order to reach this aim, the specific research questions that must be answered are:

1. While using the cruise control and speed limiter, do drivers comply more with the speed limits?
2. Do females adopt slower speeds when using speed regulating systems than males?
3. When using the cruise control and speed limiter, are drivers more prone to engage into secondary tasks?
4. Do younger drivers use the speed limiter less frequently than older drivers?

PART II. METHODOLOGY

The method adopted to gather information about the users and their experiences in the use of in-vehicle technologies was the questionnaire (the online survey was chosen as a method since the information gathered through Internet has revealed to be an advantage to get a bit number of people to answer it and because it is cheaper compared to the application of the questionnaire by hand). The questionnaire was developed in the frame of the INTERACTION project, that belongs to the 7th Framework Programme and it was built based on the results obtained by the Focus Groups sessions carried out in the first work package of the project. The questionnaire was translated in Portuguese and applied by an on-line survey company in Portugal, as well as in other countries where the project took place.

This method also offers a very flexible way of quickly collecting large amounts of specific data from a large population sample (Stanton, Salmon, Walker, Baber, & Jenkin, 2005).

Below, it is reported a list of advantages in applying the questionnaire as a methodological approach (Stanton et al., 2005):

- Questionnaires offer a very flexible way of collecting large volumes of data from large participant samples.
- When properly designed, questionnaires help in the data analysis phase turning it quick and straightforward.
- Few resources (human and monetary) are required once the questionnaire has been designed.
- It is easy to administer to large number of participants.

On the other hand, some disadvantages are also commonly recognized (Stanton et al., 2005):

- Reliability and validity of the questionnaires is questionable.
- The answers provided can be rushed and non-committal.
- Questionnaires can offer a limited output.
- Questionnaires are prone to a number of different biases.

The questionnaire was divided in 7 sections, each one including questions about a certain topic: cruise control, speed limiter, speed alert, navigation system, mobile phone, technologies in general and road safety. The questions concerning the mobile phone, technologies and road safety were applied to everyone, whereas the others were only answered if the respondent was a user, of the system under evaluation (e.g. cruise control or speed limiter).

The same questionnaire was applied in 9 countries, but only the results obtained for the Portuguese drivers will be analyzed in this study. The data was treated using the software SPSS v.20 (*Statistical Package for Social Sciences*), based on a descriptive statistics analysis. The percentages presented were all pondered to allow eliminating the differences in the sample (e.g. differences in the number of respondents for each section of questions) and comparing the data.

The Pearson Chi-square test was also run to understand if the variables were related.

To make it easier to analyze and present the data, 3 age categories were created young drivers (18-24 years), middle-aged drivers (25-54 years) and older drivers (55-74 years).

The questionnaire consisted mainly in closed questions (multiple choice, rating scales and ranking) with few open ended questions. The level of measurement of the variables was mainly continuous and categorical.

To complement the results obtained with the questionnaire, more specifically about the perceptions of the effect of speed regulating systems on secondary tasks (like mobile phone use), interviews were carried out with frequent users of speed regulating systems. The choice of interviews to complement the questionnaire was mainly motivated by the fact that this method allows the interviewer to better orient the questions and to make sure that the subjects understand what is asked to him/her.

The interviews that were applied were structured interviews. Structured interviews use a pre-defined questions design to elicit specific information regarding the subject under analysis. The content of the interview (questions and their order) is pre-determined and no scope for further discussion is permitted (Stanton et al., 2005). This type of interviews are more rigidly defined but they were more suitable for the present study, since the information required is very specific.

This interview was applied to three of the seven drivers that participated in the naturalistic driving study still in the frame of INTERACTION project. The selection of these three participants was based on the fact that they were using very often speed regulating systems, particularly the CC. The same interview was applied face-to-face to all three participants and in one case the interview was preceded by a self-confrontation moment with the driver. The reason motivating this procedure was that, during the naturalistic driving study this driver interacted some times with the mobile phone and one time with the navigation system while driving with the CC active. The driver was confronted with the videos of those interactions and, after, asked about those particular situations.

PART III. RESULTS

1.1 Cruise control results

In the total sample of 1036 respondents, 416 were users of cruise control, of which 125 (30%) were females, 289 (69.5%) were males and 2 didn't answer the question about the gender (0.5%). In the total sample that answered the questionnaire, like among CC users, the male gender was also overrepresented.

The ages of the CC users ranged from 18 to 73 years old. The mean age was 33.6 years old and the SD was 10.1 years.

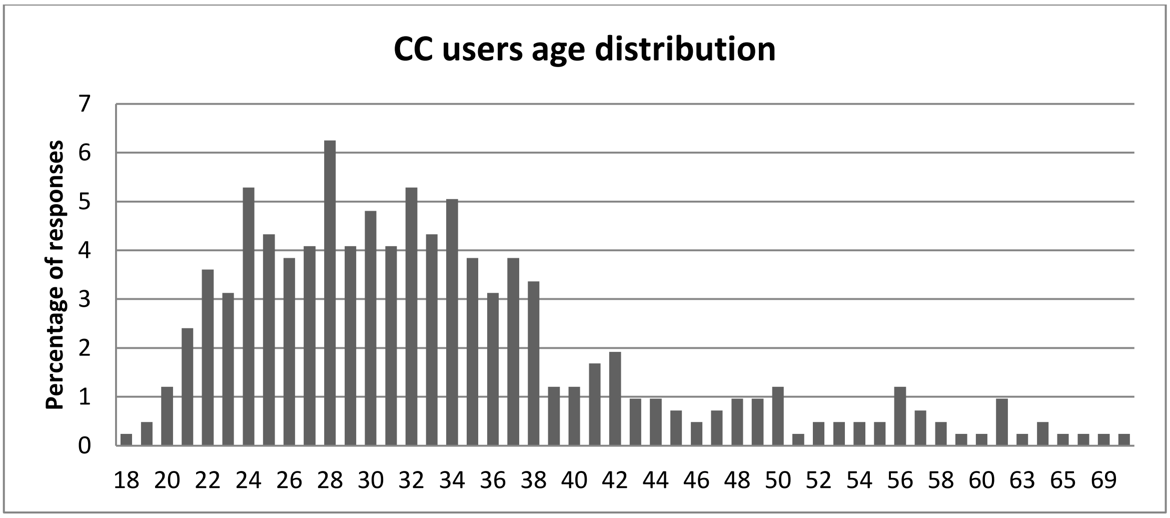

Figure 14. Histogram of the age distribution of CC respondents.

Concerning the age groups, the highest percentage of respondents belonged to the middle aged drivers (77%), 17% of the respondents were young drivers and only 6% belonged to the older drivers category (Figure 15).

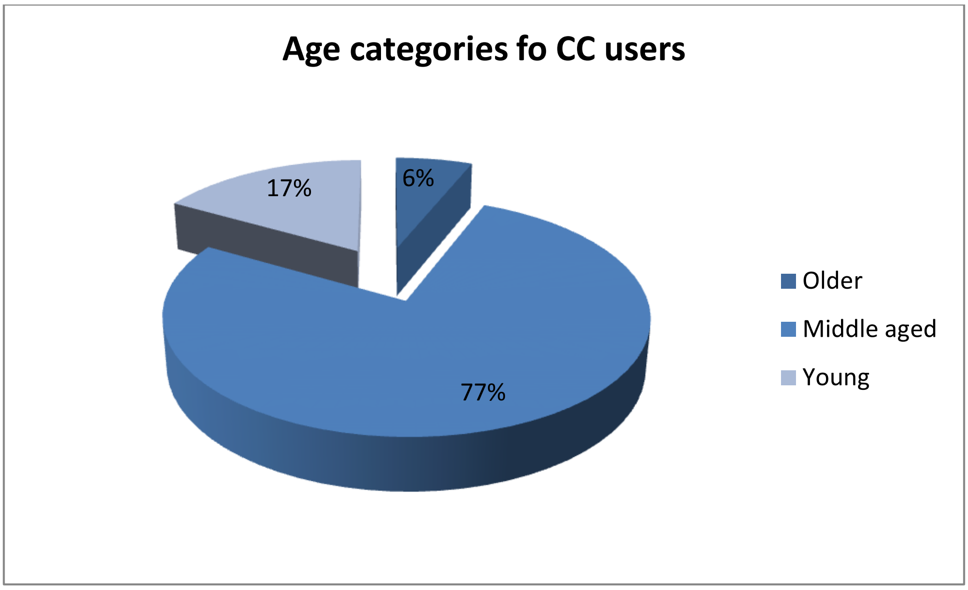

Figure 15. Pie chart with the distribution of age categories in the CC user group.

Figure 16 presents the percentage of answers from the sample concerning the years of possession of CC. With replies ranging from 1 to 13 years. The majority of respondents (68.7%) owns the system for less than 5 years.

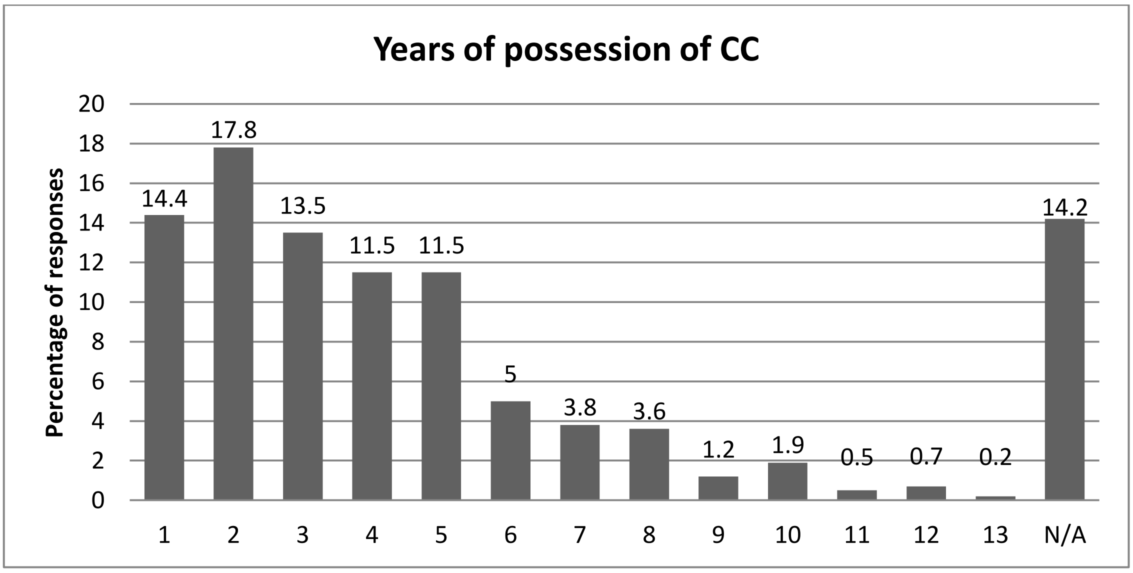

Figure 16. Number of years of possession of CC.

The participants were asked to give their opinions about the main benefits of the CC: they were asked to order the 3 most important benefits according to their opinion (Figure 17). As it can be seen, as most important benefit of CC drivers mostly mentioned the fact that it improves the comfort of driving (38.5% of the answers).

Concerning the second most considered benefit of CC, drivers reported that is that it helps to control the speed (32% of the answers). Looking at the data, we can't say that there is a clear choice about the main benefit of the CC since the percentages of the first and the second most considered benefits are not so different. The other mentioned benefits are, by far, less relevant for the users.

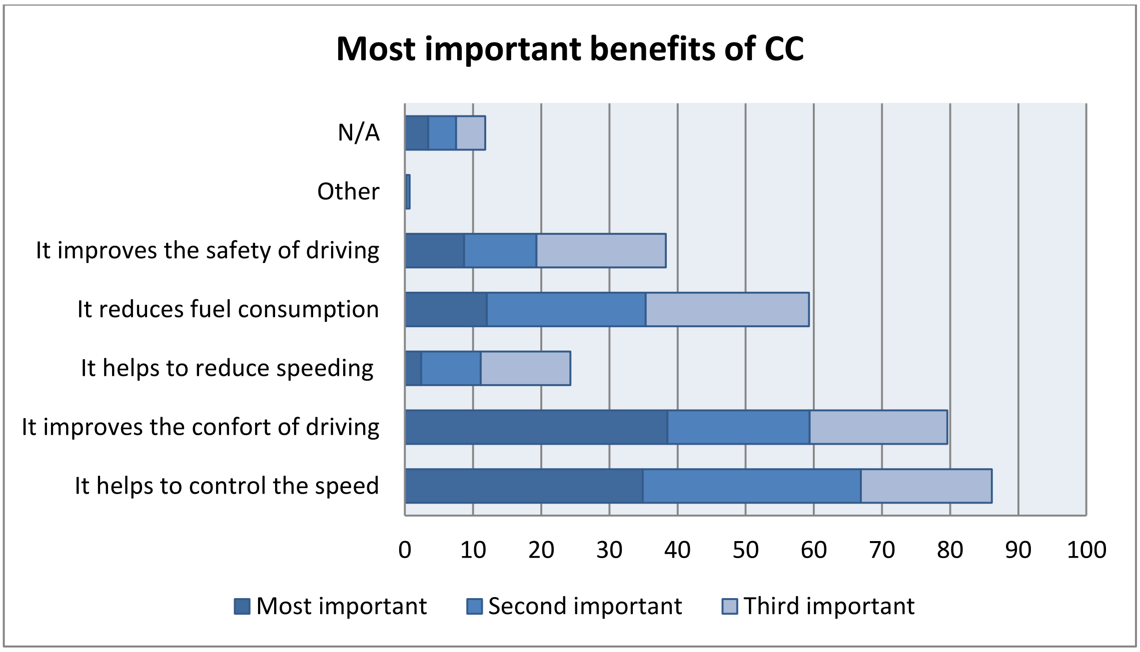

Figure 17. Opinions about the most important benefits of the CC.

Figure 18 presents a bar chart with the mean values of the perceived level of usefulness of the CC in different driving situations: the scale ranged from 0 (not useful) to 5 (very useful). The situations where respondents seem to consider the CC more useful while driving were in motorways, in long trips, in light traffic conditions, where there are speed checks and in clear weather conditions. The situations rated as less useful include road works, when there are traffic jams, special warnings, heavy traffic, when the driver is lost and city roads.

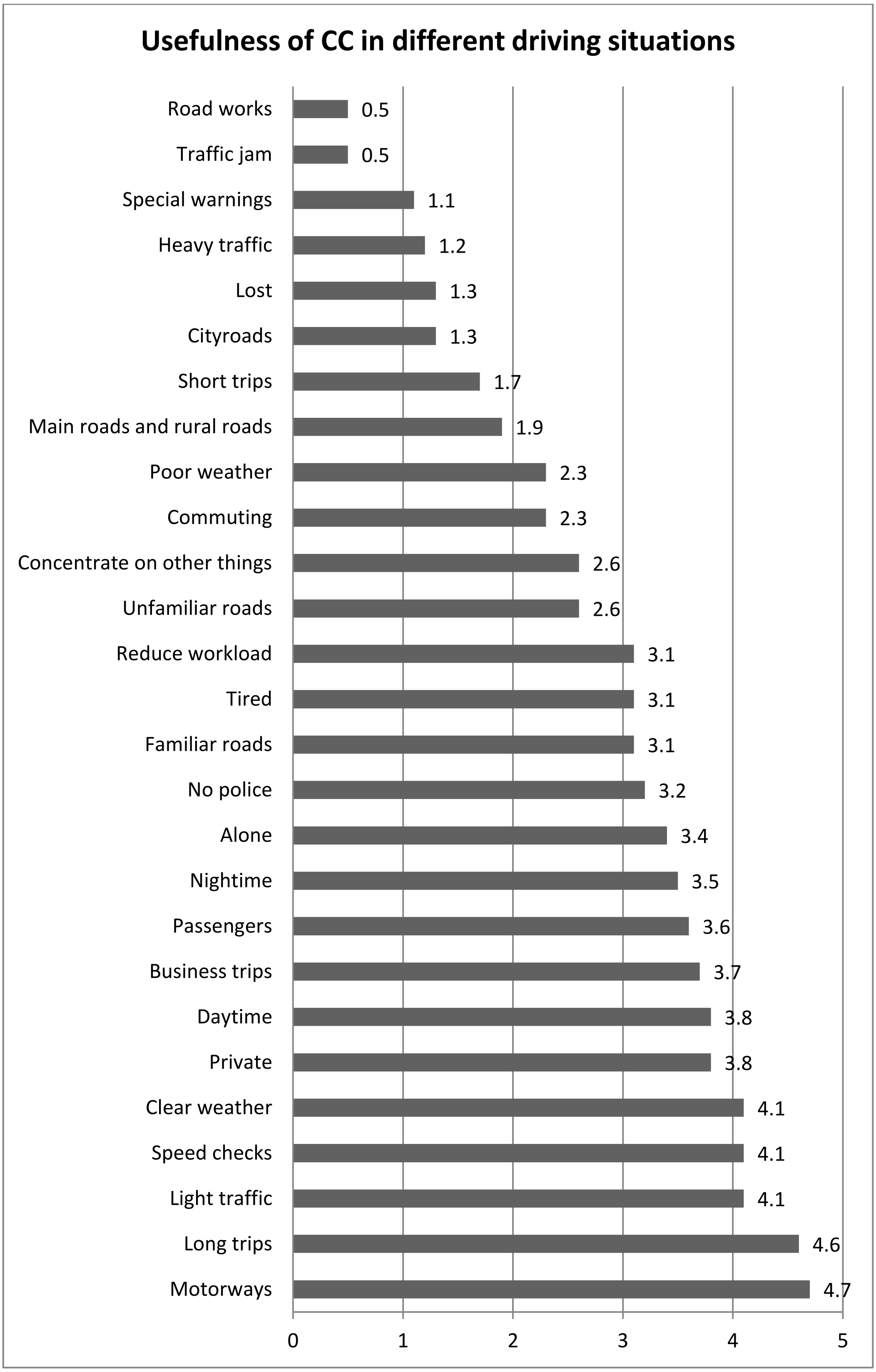

Figure 18. Bar chart with the perceived usefulness (mean value) of the CC in different driving situations.

Looking at Figure 19, it is shown the reported frequency of CC use while driving: the most reported answers were regularly, at least once a week (39.4%), and occasionally, at least once a month (33.7%).

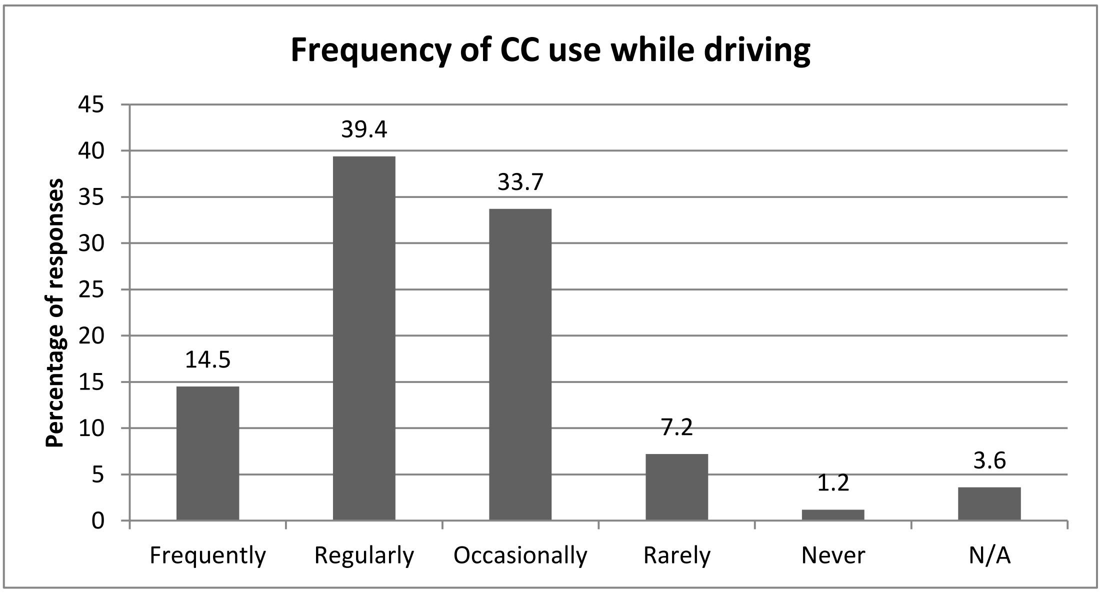

Figure 19. Reported frequency of CC use while driving.

The influence of the variables gender and age category on the frequency of CC use was analysed.

According to the Chi-square tests performed, it was found that there is a statistically significant relation between gender and frequency of CC use ($\chi2=27.96$; $p=0$), but not between the variables age category and frequency of CC use ($\chi2= 16.98$; $p=0.08$).

For what concerns the gender, in the answer ”Frequently”, the male gender is clearly more represented than females (18% against 6.4%), whereas, in the other answers the differences between genders are not significant (Figure 20). This means that males use the CC more frequently than females.

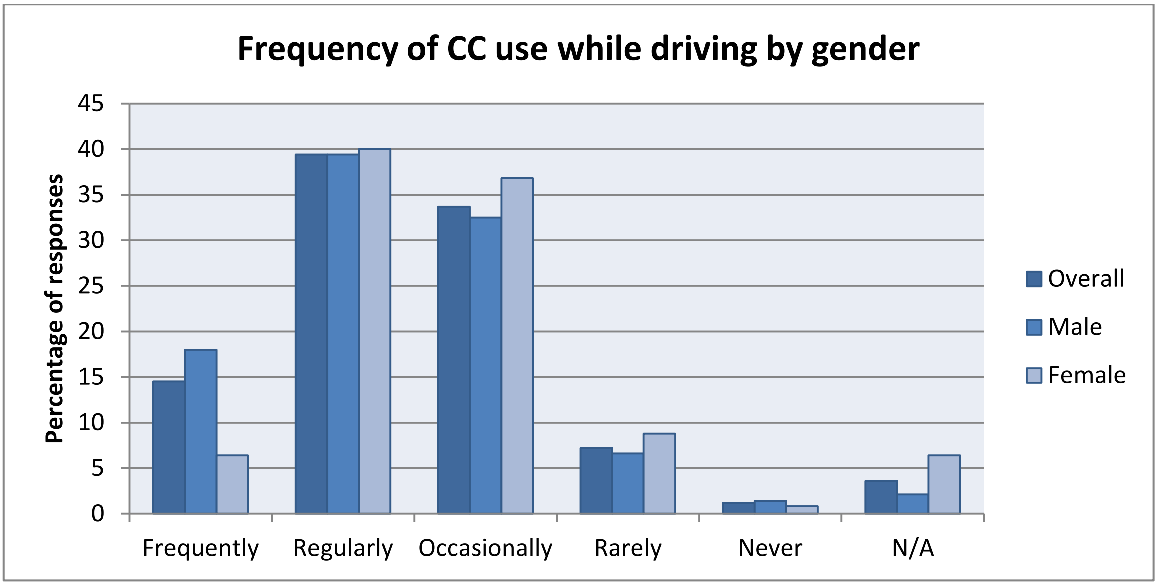

Figure 20. Reported frequency of CC use while driving by gender.

In Figure 21, it is reported the frequency of CC use by age category: we can observe that middle aged drivers are more represented in the answer "Frequently". Older drivers' most prevalent answer was "Regularly" with 64 % of answers. Young drivers, among the age graphs, were the ones with higher percentages on "Occasionally" and "Rarely", 47.1% and 10.3% respectively. Even if there is no statistical relation between variables, young drivers appeared to use the CC less frequently when compared with middle aged and older drivers.

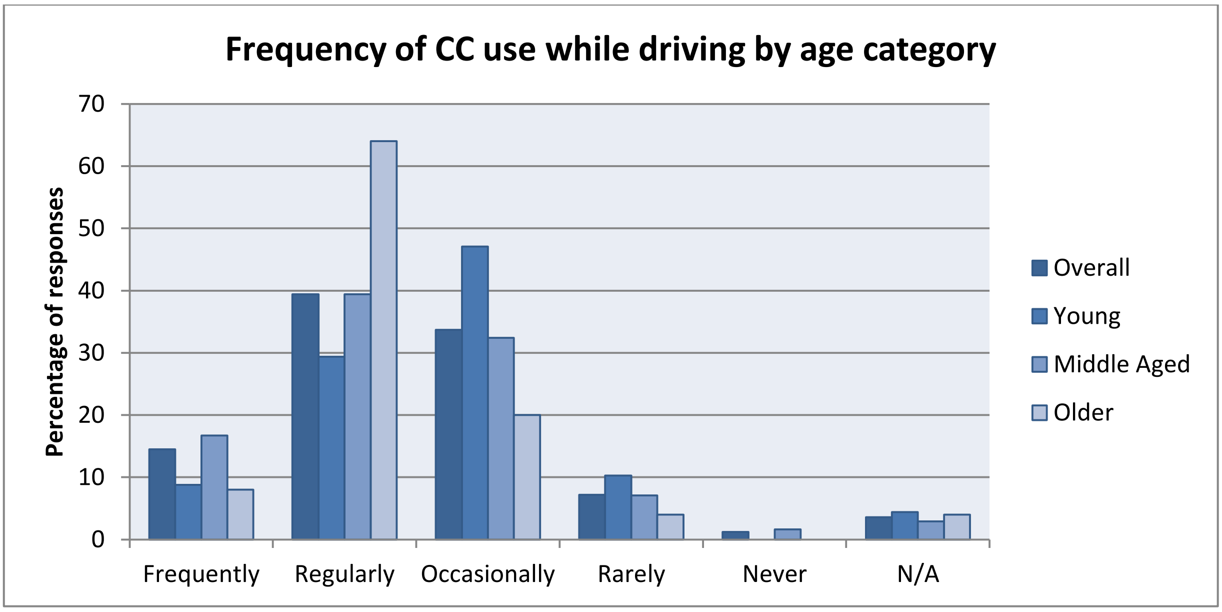

Figure 21. Reported frequency of CC use while driving by age category.

In Figure 22, it is presented the average time of CC use while driving: the answer more frequently reported was “More than half of the route” (42.5% of the total answers).

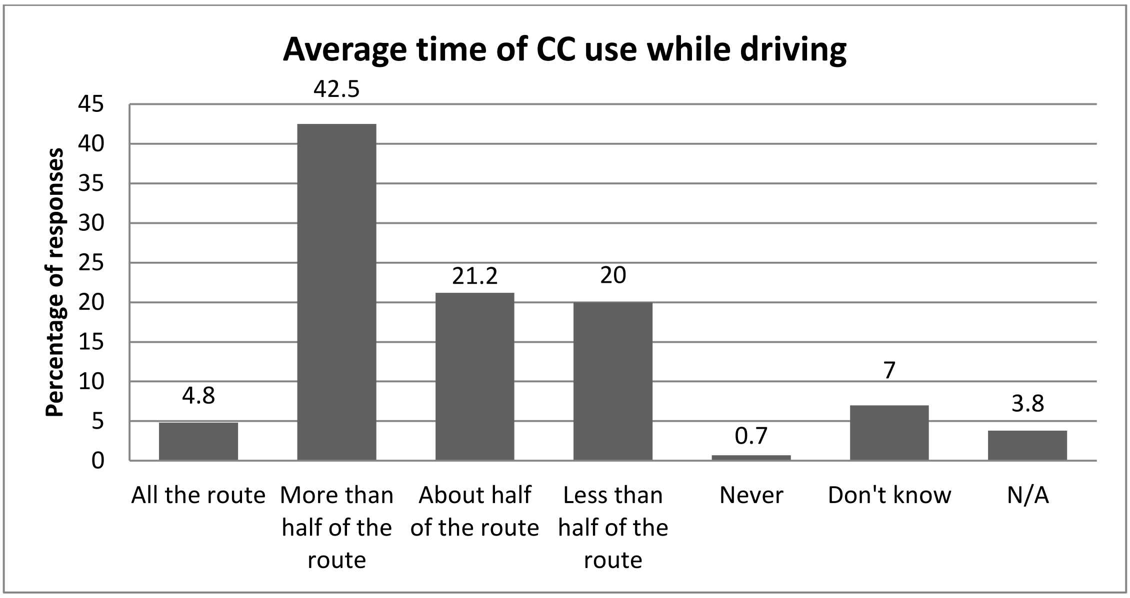

Figure 22. Reported average time of use of CC while driving.

Concerning the speeds adopted while driving with the CC, we can observe on Figure 23 that most drivers (57.7%) seem to select a speed equal to the legal speed limit. On the other hand, a conspicuous amount of drivers (26.2%) admitted to select speeds above the legal speed limit.

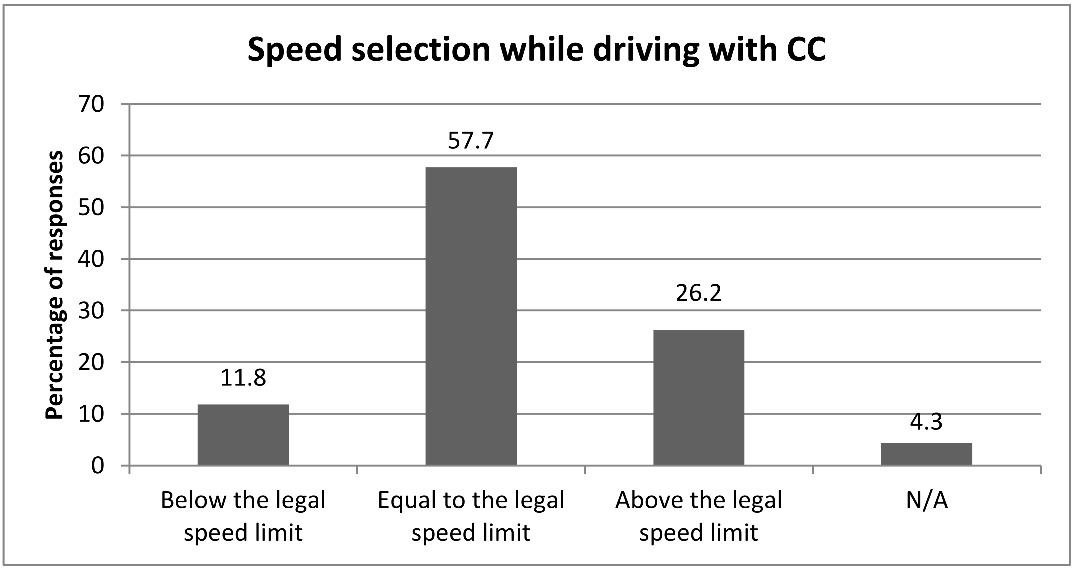

Figure 23. Reported speed selection while using the CC.

According to the Chi-square tests performed, it was found that there is a statistically significant relation between the variables gender and the speed selected with the CC ($\chi2$=22.34; *p*= 0.01). On the other hand, age category and speed selected in the CC were not statistically related ($\chi2$=7.92; *p*= 0.24).

As it can be seen on Figure 24, females seem to favour more the selection of speeds equal to the legal speed limit. On the other hand, in the answer "Above the legal speed limit" males are clearly more represented than females, (30.8% vs.16%). Globally, it seems that females are keeping the speed according to the legal speed limit whereas males choose to travel at higher speeds than the legal speed limit.

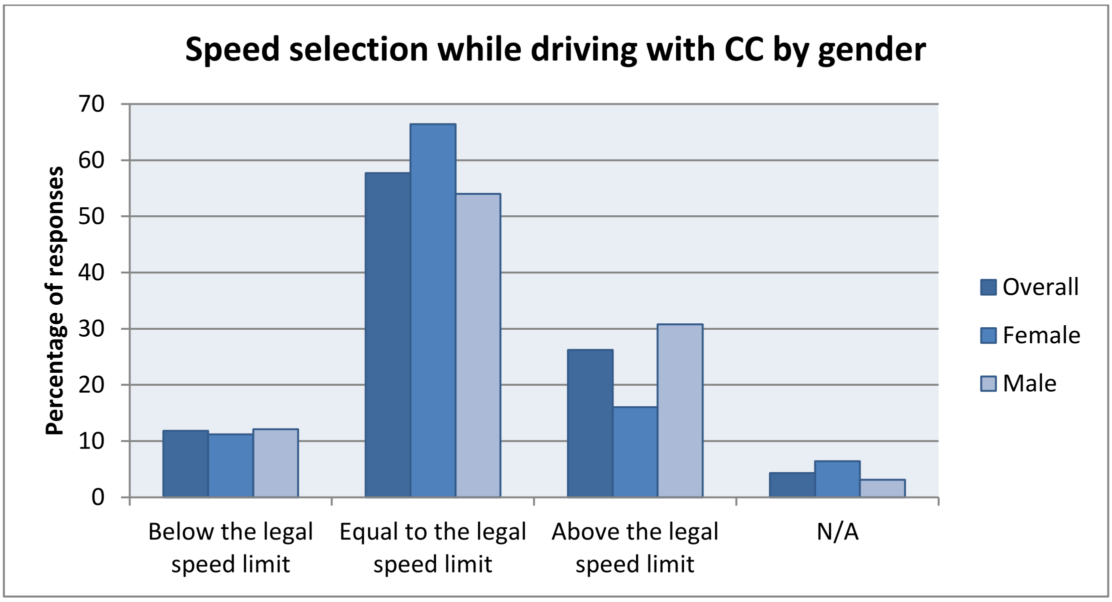

Figure 24. Reported speed selection while using the CC by gender.

Even if the variables are not statistically related, the results concerning the different age categories and the speed selection when using the CC are presented in Figure 25. Older drivers seem to be overrepresented (20%) in the answer "Below the legal speed limit" and underrepresented in the reply "Above the legal speed limit" (8%).

Young drivers were the group that more frequently admitted to set the speed with CC above the legal limit (29.4%), followed by middle aged drivers (26.6%).

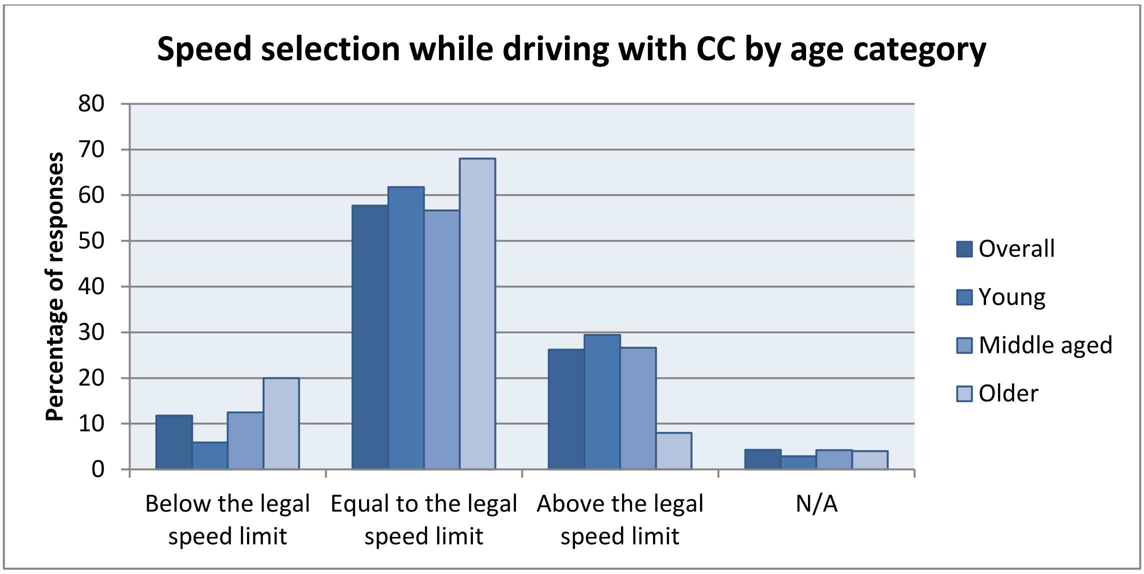

Figure 25. Reported speed selection while using the CC by age category.

Still concerning the speeds selected using the CC, the highest speed mentioned by respondents was 60 km/h above the speed limit, and the lowest one was 30 km/h below the speed limit.

In Figure 26, it is possible to observe drivers' answers to the question about their preference in making a mobile phone call while using the CC: the rate of non-answers was very high (73.2%). The low rate of responses in this question is probably due to the big size of the questionnaire, which caused tiredness to the respondents and the present question was placed at the end of the questionnaire. Looking at the valid answers 15.5% of the drivers avoided to make calls and only 9.3% mentioned to favour making calls while using the CC.

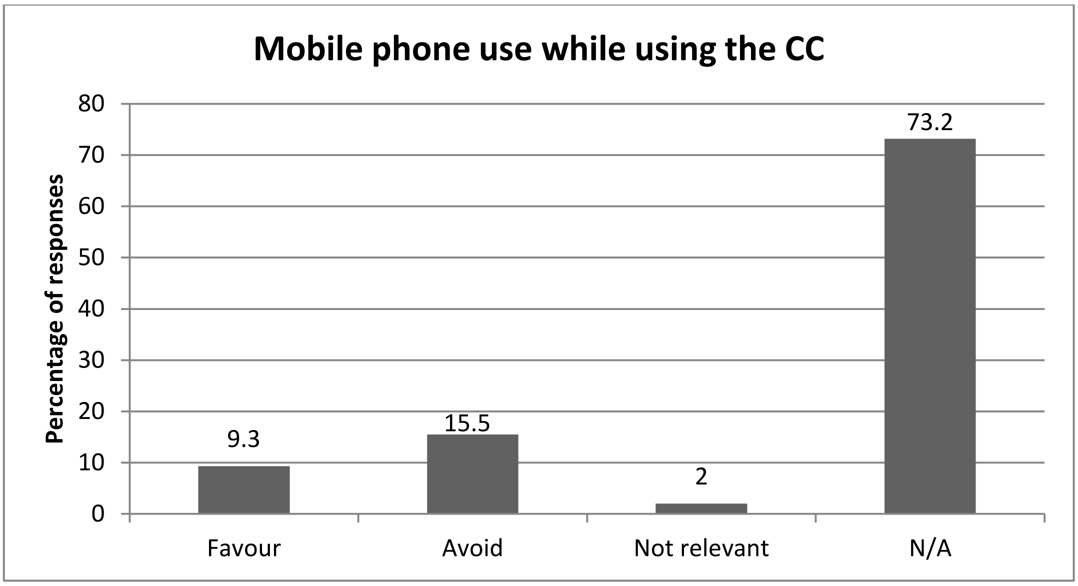

Figure 26. Reported preference in using the mobile phone to make a call while using the CC.

1.2 Speed limiter results

From the whole sample, only 265 drivers were users of speed limiter, a lower amount of people compared to CC. The speed limiter users consisted in 87 females (32.8%), 177 males (66.8%) and 1 respondent who didn't answer the gender question (0.4%). Males are still over-represented in the speed limiter users' sample.

The ages of the SL users range from 19 to 73 years old. The mean age was 34.5 years old and the SD is 10.9 years (Figure 27).

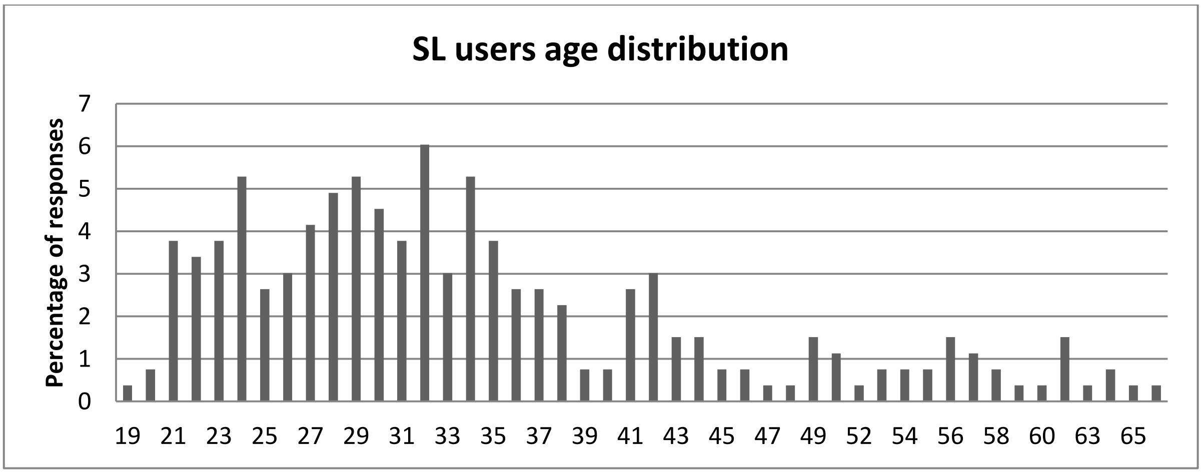

Figure 27. Histogram of the age distribution of SL users.

The age categories distribution of the speed limiter users is reported in Figure 28. The highest percentage of respondents belonged to the middle aged drivers' group (71%), 17% of the respondents were young drivers and only 8% belonged to the older drivers' group.

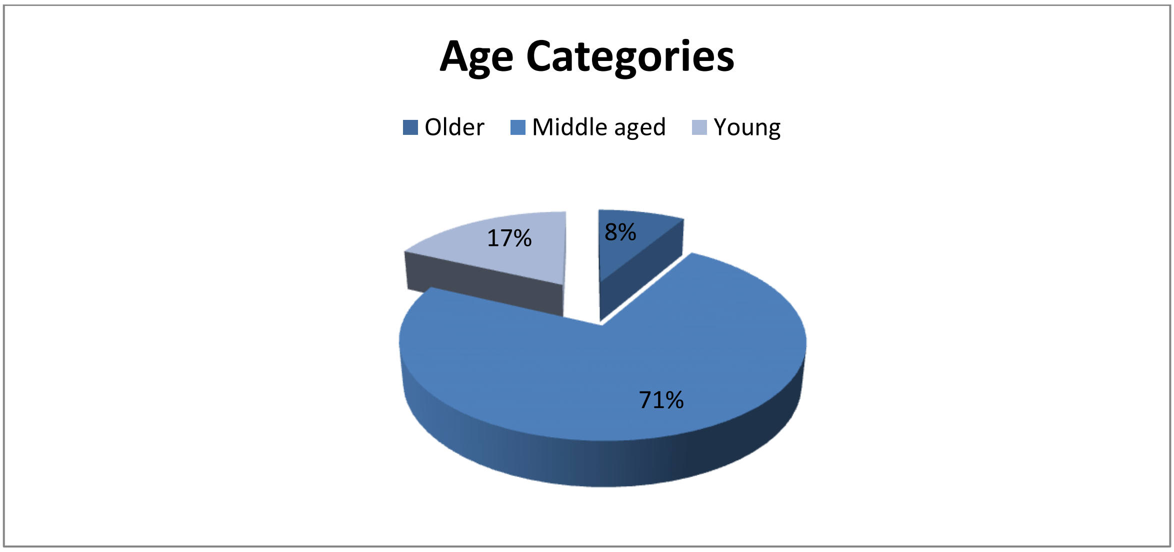

Figure 28. Pie chart with the distribution of age categories in SL user group.

In Figure 29, we can observe that the years of possession of SL ranged between "less than 1 year" and 15 years. Overall, 64.1% of the drivers possess the system for less than 5 years.

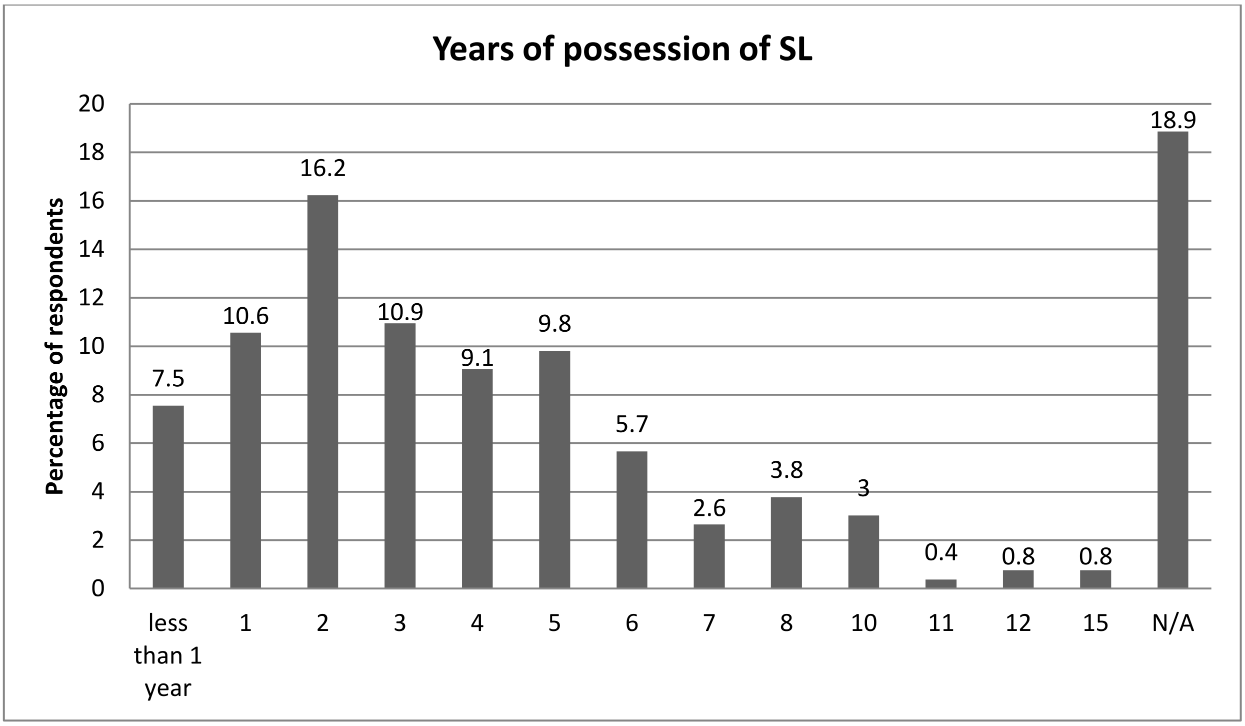

Figure 29. Number of years that users have the SL.

According to Figure 30, the most important benefit of SL was that it helps to control the speed (61.1% of the answers). The second and third most relevant benefits were, respectively, that it improves safety of driving (28.3%) and that it reduces fuel consumption (26%).

Based on the users' perceptions of the benefits of speed regulating systems, we can state that the CC is considered more important in terms of comfort (reported in 38.5% of the answers, as the most important benefit of CC) whereas the SL is evaluated as relevant in helping to control the speed.

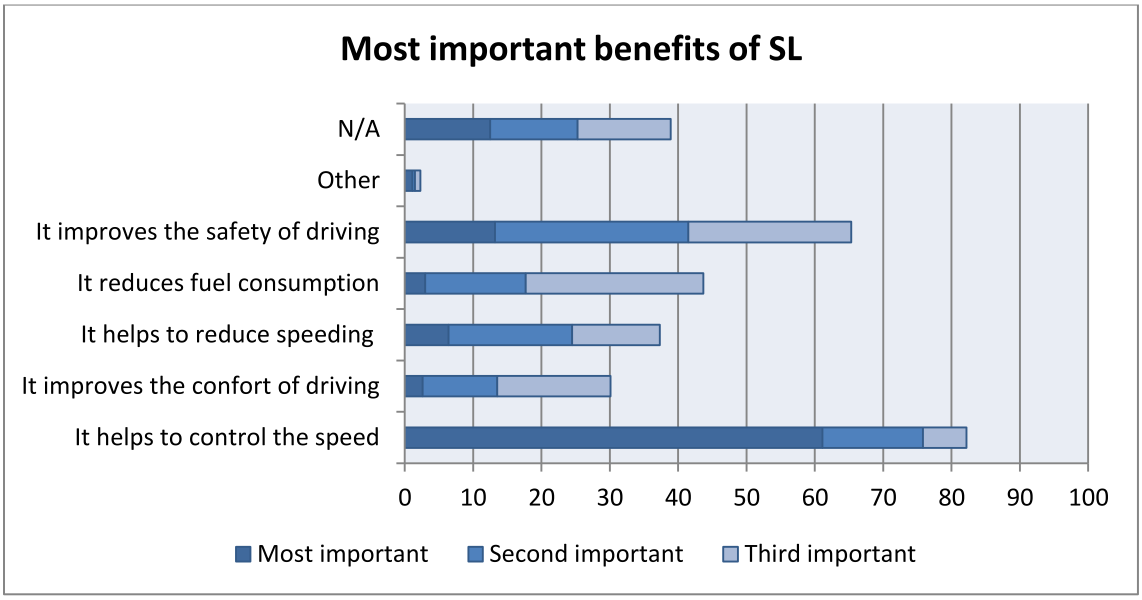

Figure 30. Opinions about the most important benefits of the SL.

Looking at Figure 31, the situations where drivers seem to consider the SL more useful were in the presence of speed checks, in motorways, in long trips, private trips, with clear weather and with light traffic. On the other hand, the situations where drivers don't consider the SL useful are in traffic jams, in roads works, roads with special warnings, when the driver is lost, in heavy traffic and in short trips.

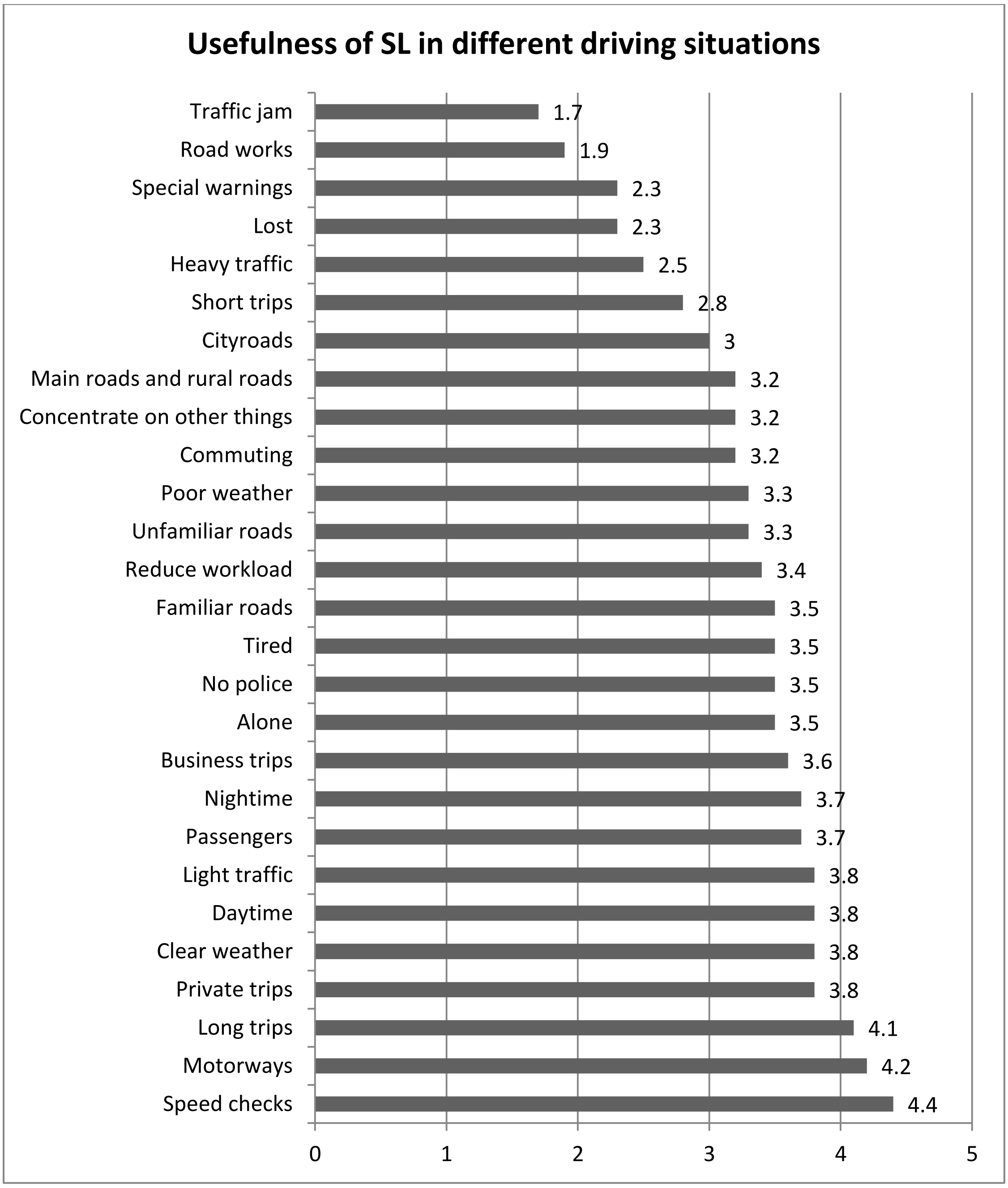

Figure 31. Bar chart with the perceived usefulness (mean value) of the SL in different driving situations.

The reported frequency of SL use while driving for 36.2% of the drivers was regularly (at least once a week). The SL is used occasionally (at least once a month) by 22.6% of the drivers and frequently (at least once a day) by 14.7% of the drivers (Figure 32).

Comparing the opinions about the frequency of use of the SL and the CC, it seems that the results are alike, even though the numbers of “Non-answered” and “Never” answers are higher in the SL. In general comparing the SL and CC results, the CC was slightly more used than the CC.

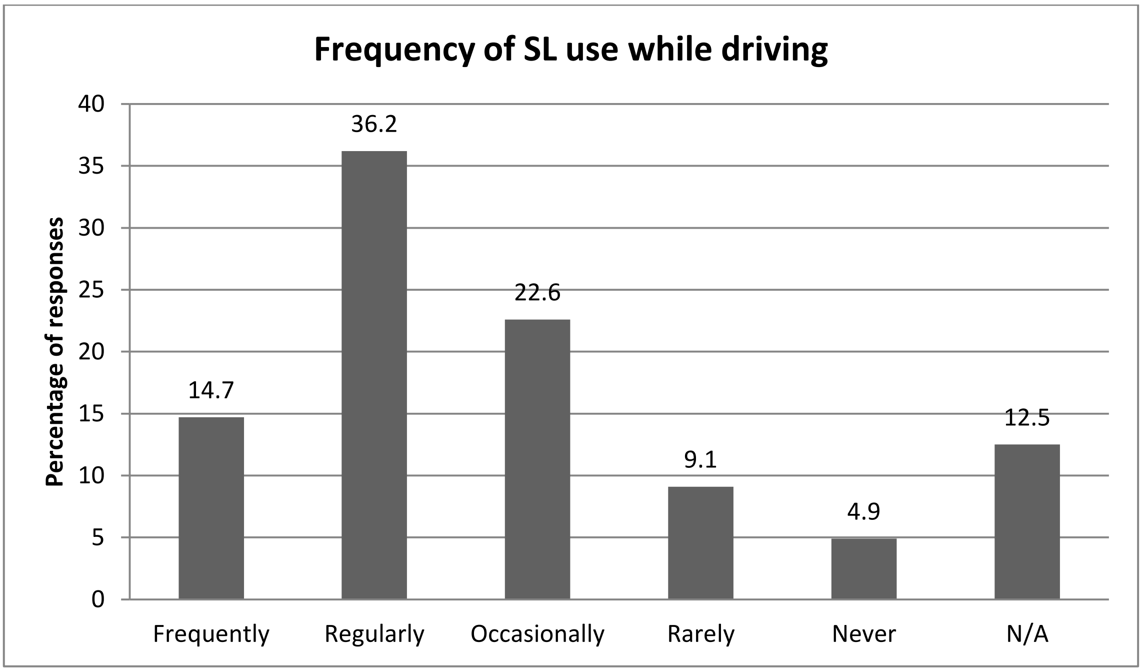

Figure 32. Reported frequency of SL use while driving.

The reported frequency of SL use while driving was analyzed by “gender” and “age category”.

According to the Chi-square tests performed, it was found that there is no statistically significant relation between gender and the frequency of SL use ($\chi 2$=20.19; *p*= 0.28) and neither between the variables age category and the frequency of SL use ($\chi 2$=15.39; *p*= 0.12).

However, according to Figure 33, in the answer “Regularly” males are clearly more represented than females (42.4% against 24.1%). On the other hand, in the answer “Occasionally”, females are more represented than males (28.7% against 19.8%). Even if the variables are not statistically related, it seems that males use the SL more frequently than females.

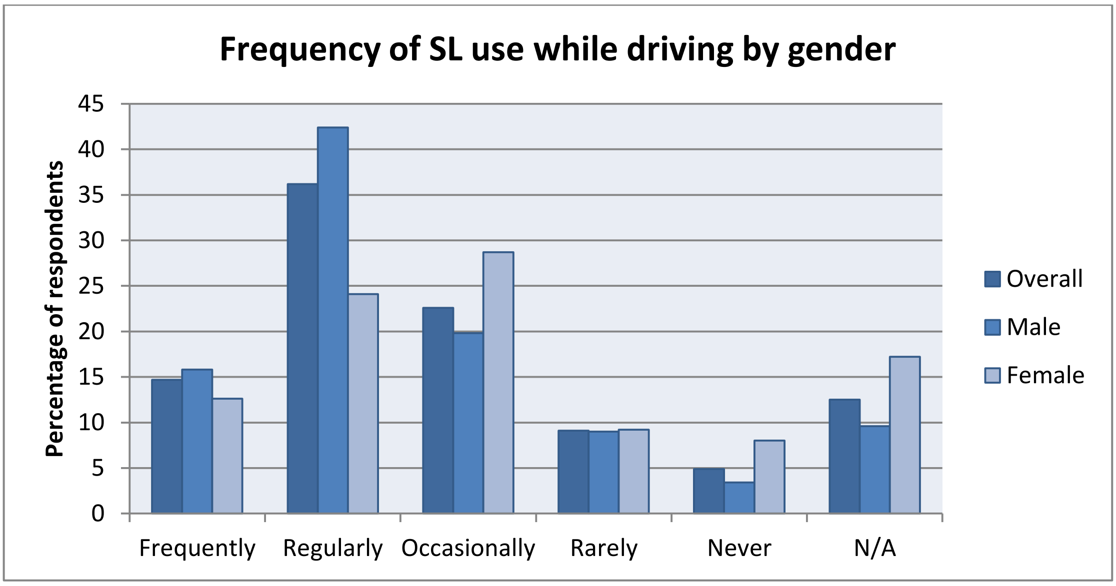

Figure 33. Reported frequency of SL use while driving by gender.

Concerning the age categories, as it can be seen on Figure 34, the drivers that stated to use the SL frequently were mainly middle aged drivers (17%). On the other hand, older drivers' most prevalent answer was regularly (at least once a week) with 54.5% of answers and young drivers were prevalently occasional users of SL (37%). As the results obtained for the CC, it seems that young drivers are less prone to use the SL while driving.

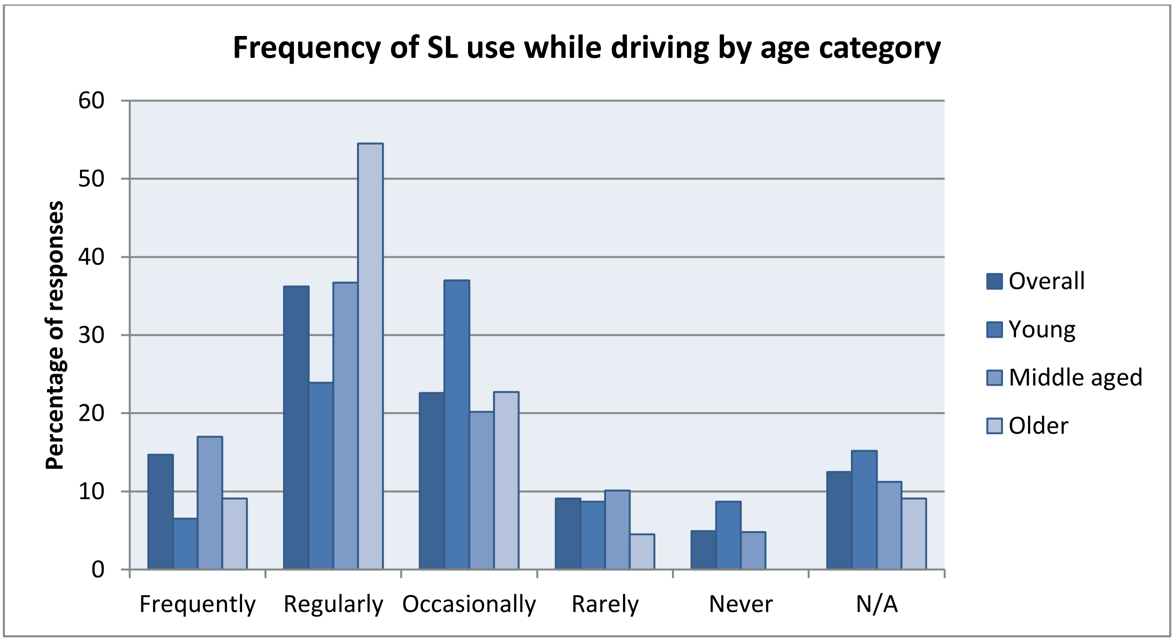

Figure 34. Reported frequency of SL use while driving by age category.

In Figure 35, it is presented the average time of SL use while driving, the answers more frequently reported were “More than half of the route” (27.5%) and “Less than half of the route” (26.8%). Compared to the results obtained for the CC, the SL seems to be used, in average, for less time during a trip.

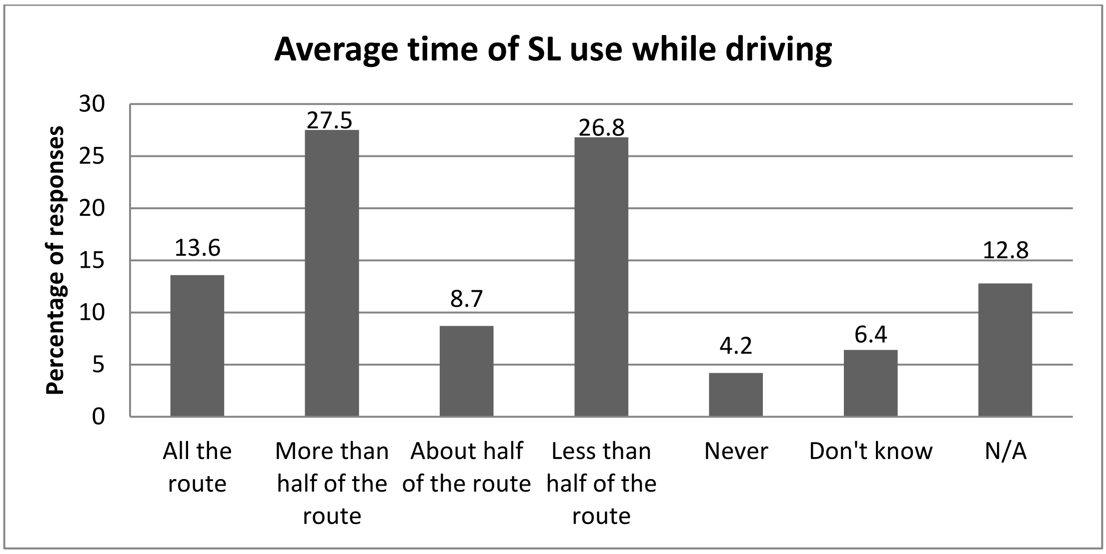

Figure 35. Reported average time of use of SL while driving.

In Figure 36 we can observe the speeds selected while driving with the SL. Most drivers (57.7%) seem to select a speed equal to the legal speed limit, 17% of the sample admitted to select speeds below the legal speed limit and only 9.8% reported to select speeds above the legal speed limit.

The percentage of drivers that reported to select speeds above the legal speed limit while using the SL is lower than the one that mentioned to select speeds below the legal speed limit. For the usage of the CC situation was the opposite, with a percentage of “Below the legal speed limit” answers was much lower than the “Above the legal speed limit” answers (11.8% vs. 26.2% respectively). In any case, for both systems, the most prevalent speed selection patterns correspond to the adoption of speeds equal to the legal speed limit.

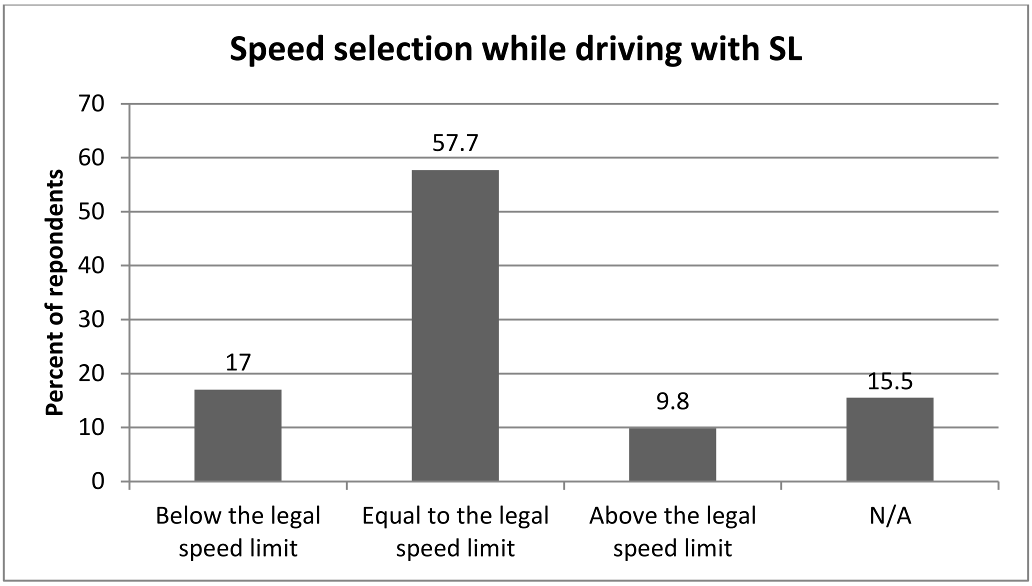

Figure 36. Reported speed selection while using the SL.

According to the Chi-square tests performed, it was found that there is no statistically significant relation between the variables gender and the speed selected with the SL ($\chi 2$=9.74; p= 0.14) and between the variables age category and the speed selected with the SL ($\chi 2$=4.36; p= 0.63).

The results of the speed selection while using the SL by gender and by age category are presented below even if their relations are not statistically significant (Figure 37 and Figure 38). Concerning the gender, females are slightly more represented than males in the categories “Below the legal speed limit” (19.5% vs. 18.1%) and “Equal to the legal speed limit” (59.8% vs. 57.1%). On the other hand, males are more represented in the answer “Above the legal speed limit” (11.9% vs. 5.7%).

For both systems, CC and SL, females mentioned to keep more frequently the selected speed equal to the legal speed limit. Besides, they appeared to be less prone to select speeds above the legal speed limit, compared to the males.

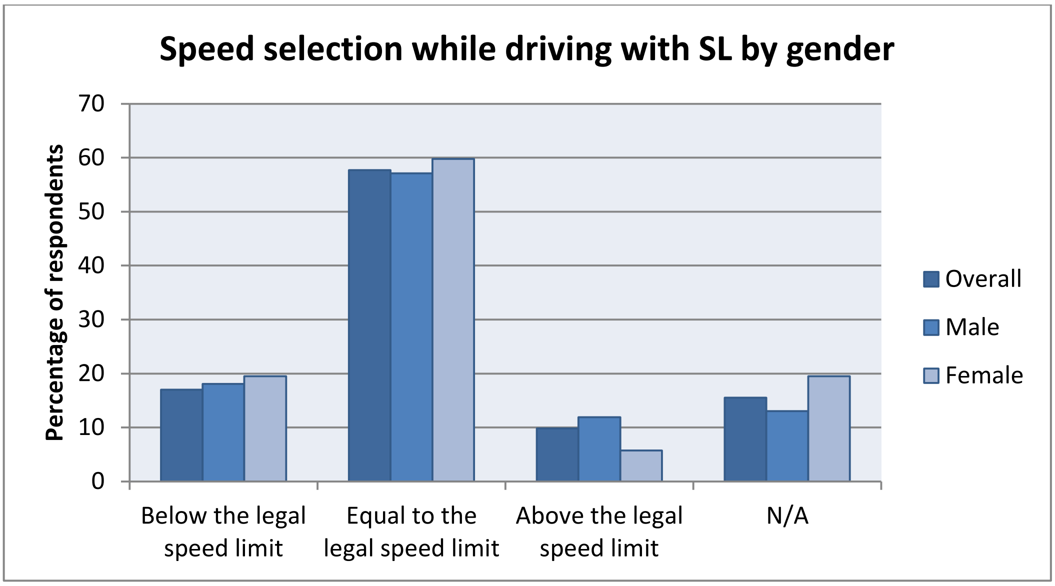

Figure 37. Reported speed selection while using the SL by gender.

Focusing on the age category, in the answer “Below the legal speed limit” and “Equal to the speed limit”, older drivers were the most represented. Middle aged drivers are more represented for what concerns the selection of speeds above the legal speed limit with 11.7% (young drivers and older drivers had percentages of respectively 4.3% and 4.5%).

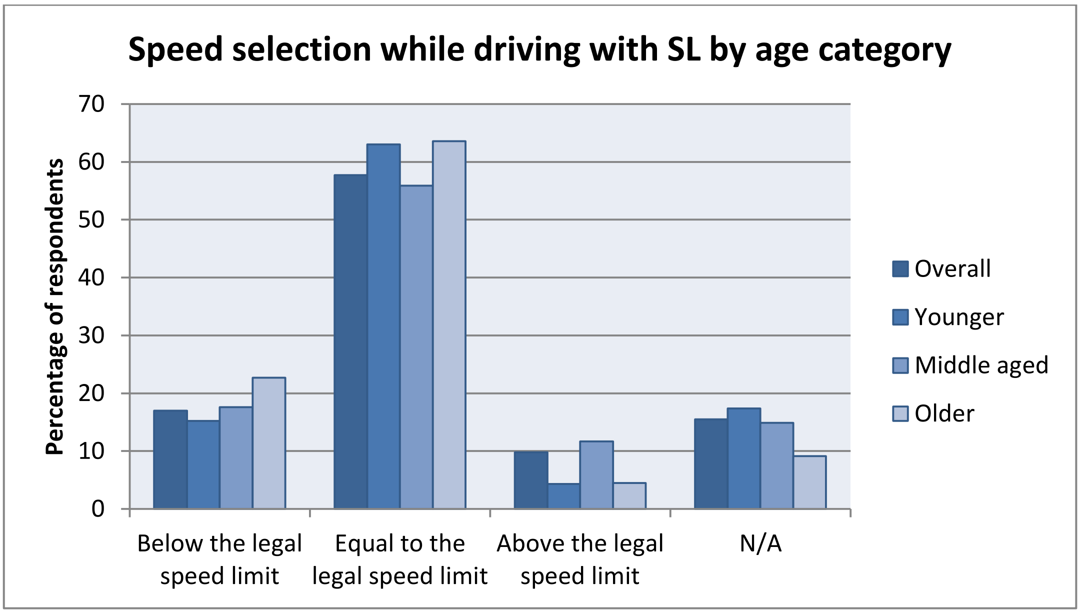

Figure 38. Reported speed selection while using the SL by age category.

Still concerning the speeds selected while using the SL, the highest speed mentioned by respondents was 40 km/h above the speed limit and the lowest one was 30 km/h below the speed limit.

Concerning the preference of making a phone call while using the SL, the percentage of drivers that didn't answer the question was very high (84.5%). As already reported for low rate of responses in this question might be caused by the big size of the questionnaire. Considering the remaining answers, 9.4% of the drivers avoided to call whereas 4.5% mentioned to favour it. The percentage of respondents that favoured to use the mobile phone when using the system was slightly higher compared to the results obtained for the CC, but the difference was not relevant enough to make a distinction between systems.

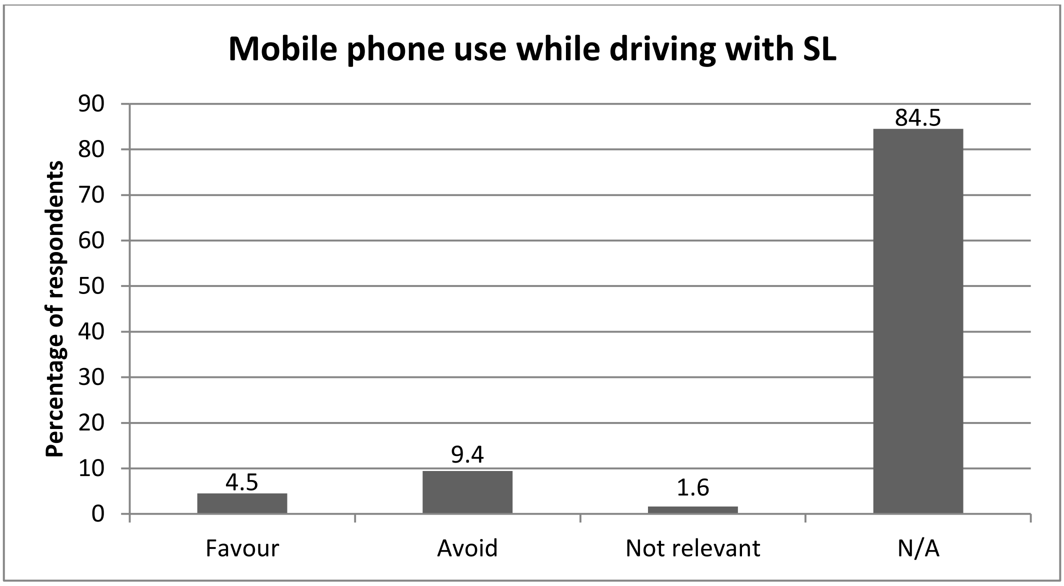

Figure 39. Reported preference in using the mobile phone to make a call while using the SL.

1.3 Interview results

The results collected were not sufficient test the hypothesis "When using the speed regulation systems drivers are more prone to engage into secondary tasks". Indeed, the rate of valid answers to the question concerning the preference about making a mobile phone call while using the CC or the SL was very low. In order to overcome the issue related to the low number of replies and, considering this question important in the frame of the present study, it was decided to carry out interviews with the participants of the naturalistic driving study to further explore the matter (topic).

It should be noted that two of the participants were using more frequently the CC when compared to the SL, and one participant is using the SL more frequently. And the two more frequent CC users admitted to engage into other tasks (mainly mobile phone use and talking to other passengers) while driving with the CC active.

The participant who performed secondary tasks (mobile phone use and navigation system programming) while driving with the CC activated in the naturalistic driving study, answered, during the interview, that, the manipulation of those systems when the CC was active was intentional. He mentioned that he needed to call, concerning the mobile phone, and, for the navigation system that he wanted to know at what time he would be arriving.

Among the three participants, two of them considered that when the CC is active, the driver is more likely to engage into other tasks. One of them added that even though the system was not designed for drivers to focus on other tasks, it actually happens. When asked if they performed other tasks while the CC was activated, the answer was positive, but one of them added that he only performs other tasks when the road is free (with low or inexistent traffic). The secondary tasks that the participants mentioned to perform with the CC activated were using the mobile phone and talking with passengers. The third participant had a different idea: she reported that, when the CC is active, she doesn't engage into other tasks and, on the contrary she is more alert than during regular driving because the vehicle is not being controlled by her.

When asked if they ever activated the CC to focus on another task different from driving, all the replies were negative, with two of the respondents which answered to activate the system to drive more relaxed and only when the traffic allows to do it.

All participants admitted to have already felt monotony while driving with the CC activated. For two of them, the factor having more impact on the monotony was the road environment, even if the use of CC could aggravate that state, for the other participant, the more relevant factor for monotony was the CC use. Concerning the actions taken to avoid the monotony, they mentioned talking with passengers, talking on the phone, driving faster, stopping to rest and simply deactivating the CC.

Participants didn't think that, since they drive vehicles equipped with the CC their predisposition to engage in secondary tasks increased.

Finally, participants didn't have the same opinion about the SL compared with the CC as they didn't seem to have ever activated that system and engage into a secondary task at the same time. Anyway, one of the participants admitted to use the SL in roads with traffic lights triggered by speed, so that she can look outside without being worried about making the traffic lights turn red.

Summary of the main findings:

- Based on the users' perceptions of the benefits of CC and SL, we can state that the CC most considered benefits were the comfort (reported in 38.5% of the answers) and helping to control the speed (32% of the answers). The SL is mainly considered as a system that helps to control the speed (61.1% of the answers). The second and third most relevant benefits were respectively that it improves safety of driving (28.3%) and that it reduces fuel consumption (26%);
- Males use the CC and the SL more frequently than females;
- For both systems, CC and SL, it seems that young drivers are the age group that appears to be less prone to use them while driving;
- The percentage of drivers that answered to select speeds above the legal speed limit while using the SL is lower than the ones that answered to select speeds below the legal speed limit. Concerning the CC the opinions obtained were opposite, since the percentage of the selection of speeds below the legal speed limit was much lower than the selection of speeds above the legal speed limit (11.8% vs. 26.2% respectively). However, for both systems, the most prevalent answer was to select the speed equal to the legal speed limit;
- In both systems, CC and SL, females seem to be more willing to keep the selected speed equal to the legal speed limit compared to males. They are also clearly less represented for what concerns the habit of selecting speeds above the legal speed limit;
- For both systems, middle aged drivers were the age group that was more represented in keeping speeds above the speed limit. Older drivers are the age

group that is more represented as choosing speeds equal to the speed limit in both CC and SL;

- Between the two speed regulating systems, CC and SL, it seems that the CC has a bigger impact when it comes to engaging into secondary tasks while driving. However from the interview, it seems that the engagement into secondary tasks is not the reason leading people to activate the CC but, rather, the consequence of the available resources due to the usage of the CC during the driving task;
- The SL doesn't seem to promote the performance of secondary tasks while driving with the system active.

PART IV. DISCUSSION

The most reported benefit of the CC was that it improves the comfort of driving (38.5% of the answers). Since the driver doesn't have to accelerate when the CC is activated, his inferior members are more free to adopt different positions, or to rest and therefore, the fatigue is reduced. This advantage had been already recognized in previous studies (Lheureux, Saad, Pianelli, Abric, & Roland, 2006; Bauer et al., 2006). On the other hand, Young and Reagan (2007) found that Australian drivers main motivation for using the CC was to avoid speeding fines, even though they also mention comfort as an advantage. The difference in the results might be due to the large distinctions in speed enforcement policies between countries. Indeed, Portugal is one of the European countries where speed limit violations are less detected and penalized (6% in the last 3 years), comparing the results with the Netherlands (46%) or with Germany (36%) (SARTRE 3, 2004).

According to the respondents, the most important benefit of SL is that it helps to control the speed (61.1% of the answers). Lheureux, et al. (2006) had similar results, they found that, approximately, 20% of the SL users stated, as motive to own the system, "In order not to worry about the police checks", which implies the function of controlling the speed.

In spite of both CC and SL being speed regulating systems, it seems that drivers recognize different roles to each of them. CC is considered, firstly, as a comfort system and, only after that, drivers admit its benefit in controlling speed. As for the SL, the main benefit was, without any doubt, identified as being the speed control.

The situations where respondents seem to consider the CC more useful while driving were in motorways, in long trips, in light traffic conditions, where there are speed checks and in clear weather conditions. The situations rated as less useful include road works, when there are traffic jams, special warnings, heavy traffic, when the driver is lost and city roads. These findings are similar to previous studies (Bauer et al., 2006; Young & Reagan, 2007; Lheureux et al., 2006).

Drivers considered the SL more useful in the presence of speed checks, in motorways, in long trips, private trips, with clear weather and with light traffic. On the other hand, the situations where drivers don't consider the SL useful are in traffic jams, in roads works, roads with special warnings, when the driver is lost, in heavy traffic and in short trips. The results reached by Lheureux et al. (2006) seem to confirm the findings obtained in this study but it seems that even though participants considered the SL use favorable in "rural roads" and "motorways". On the other hand, Várhelyi and Mäkinen (2001) found that the acceptance of speed limits was higher in built-up areas (city roads). In the present study the preference for the SL use in motorways might be related to the fact that motorways have, usually, less traffic and on the other hand, drivers might avoid to use the SL in city roads because, there, speed limits are constantly changing (therefore, the driver has to constantly change the speed value when the system is activated).

Overall, it seems that drivers prefer to use CC and SL in similar conditions: in roads with light traffic (motorways), with speed checks; conversely, the systems are considered less useful in roads with heavy traffic.

Males use the CC more frequently than females and, even if the variables (Gender and SL use) are not statistically related, it also seems that males use the SL more frequently than females. These findings are confirmed by Lheureux et al. (2006) but only for the SL since it seems that no impact was found from gender on the CC use. There is no apparent reason to explain the prevalent usage of CC and SL by males, but it seems that, in general, females use less frequently speed regulating systems. The opposite situation was to be expected since Yagil (1998) found that females had a stronger sense of obligation to obey traffic laws. It is also possible that males are more interested in technology in general, therefore, they use it more often.

Even if there is no statistical relation between age and CC/SL use, it seems that young drivers tend to use both the CC and SL less frequently compared with middle aged and older drivers. One explanation for this result might be that young drivers are reluctant to accept so well systems that control their speed. Lheureux et al. (2006) didn't find any evidence about the influence of age on the use of both, CC and SL. Young, Regan, Triggs, Jontof-Hutter, & Newstead (2010), in a study about the effects and acceptance of Intelligent Speed Adaptation systems (ISA) found that those systems appear to be more effective at reducing speeds for experienced drivers on arterial (60 km/h) and residential (50 and 60 km/h) speed zones. On the other hand, the same effect could not be found for inexperienced drivers which even increased speeds with use of the ISA-A (system that combined a visual warning and a counterforce on the accelerator pedal when the posted speed limit was exceeded by 2 km/h or more). Considering that, usually, inexperienced drivers are younger drivers, the findings from Young et al. (2010) seem to show that younger drivers do not comply with speed limits when using the speed regulating system. Besides, Lajunen and Parker (2001) found that aggressive driving was most associated with the lower age groups, probably meaning that younger groups are reluctant to control their speed. According to the results obtained in the studies mentioned above, the less frequent use of the CC and SL for younger drivers can be related to their unwillingness to comply with imposed speed limits.

Comparing the results obtained about the average time of use for CC and SL, it seems that the SL is used for less time during a trip: this finding is most likely related to the speed restricting (controlling) function of the system which might make drivers willing to use the SL for less time and in more specific situations (like areas with speed radars).

Concerning the speeds adopted while driving with CC and SL, most drivers affirmed to select speeds equal or below the legal speed limit (69.5% of the drivers for CC and 74.7% for SL). So according to the results, it seems that speed regulating systems are mostly used to comply with speed limits. Between the two systems, the SL seems to be slightly more used for speed compliance. Similar results were found by Lheureux et al. (2006), where both CC and SL were perceived as beneficial towards speed compliance with the speed limiter having a greater effect in making people drive slower than with the CC.

Unlike Lheureux et al. (2006), it was found that there are gender differences in the speeds adopted while driving with the CC activated. Notably, it seems females are more effective in keeping the speed according to the legal speed limit, whereas males choose to travel at speeds higher than the legal speed limit. This result can be explained by the fact that females tend to disregard less the speed limits and other traffic rules when compared to males (Norris et al. 2000).

According to the results obtained in the questionnaire and interviews subsequently carried out, it seems that the CC has a greater impact on drivers' predisposition to engage into secondary tasks while driving: the most reported secondary task when driving with the CC active is the mobile phone use. However, in order to draw some conclusions it is very important to consider the habits of drivers in the context of the country where the research was performed: according to Ferreira, Piccinini, Rôla and Simões (2012), it seems that 28.5% of Portuguese drivers are frequent users (at least, once a day) of mobile phone while driving. This percentage is high considering that according to the article 84 of the Portuguese law, the use of hand-held mobile phone while driving is forbidden (despite being allowed the use of hands-free devices, except the ones that cover both ears). Using the mobile phone while driving is a severe offence, which might lead to a minimum driving inhibition of one month until one year and a fine ranging from 120 to 600 Euros (Autoridade Nacional Segurança Rodoviária, 2012).

During the interview, the two drivers that admitted to perform other tasks while driving with the CC active, mentioned to do it in highway context or in roads with little or inexistent traffic, meaning that they prefer to engage into secondary tasks when the environment is less dynamic. This phenomenon can be explained by Hockey's (1997) compensatory control model, already described in chapter 5 (about automation and behavioural adaptation). According to this model, due to the low mental workload (associated to an activity that changes the role of the human to a supervisory one due to two factors, road environment and CC use), it seems that these drivers engage into secondary tasks as a way to increase workload to an optimum level. Apparently, drivers seem to be more likely to engage into secondary with the CC, however, further research is needed to draw conclusions on this.

According to the questionnaire results and the interviews, it seems that the SL usage is not considered to have an effect on the performance of secondary tasks. This finding can be explained by differences in the level of automation existing between the two systems, CC and SL and also, by the function of each system, CC the comfort whereas SL controls the speed. The CC partly automates the driving task, acting out the tactical level of Michon's hierarchical driving task model (after choosing the speed, the driver just needs to steer and to monitor the road in order to be able to take back control of the vehicle if necessary). On the other hand, the SL is not changing so much the driving task because it only prevents the vehicle to overcome the chosen speed.

It should be noted that the two drivers which admitted to engage into secondary tasks were experienced CC users; on the contrary, the participant who stated not to engage into secondary task, was mainly a SL user. Based on that we might assume that experience and acceptance about CC, influences the predisposition to engage into a secondary task. However, further investigation is required to confirm this assumption.

Finally, based on this work there are a set of recommendations which could be interesting for the further development and safe usage of those systems.

- Information

Drivers should be informed about the proper usage of the systems. The information should be available in the simplest and most effective way. Vehicles equipped with these systems could include a simple sheet with some pictures or illustrations explaining the correct use step by step. Car sellers also could play a relevant part in informing people on how to use those systems.

- Training

Drivers should know what is the aim of the system, in which contexts it should be used, and systems' limitations. Until now, people have been mostly learning how to use the systems by themselves or through friends and family. The training should start in driving schools thought both theory and practice on how to use the systems in a real context. For those that already have a driving license, the car sellers should be responsible for providing the theory and the opportunity to try the systems. However, after attending the training, the legal responsibility in the correct usage of the systems is always on the driver.

- Speed limiter should evolve to a more "intelligent" concept

In a normal speed limiter, the driver has to choose the speed. However, if the system could automatically detect speed limits and would adjust or suggest the speed accordingly it would be possible that the speed complying potential of the system would be increased. In the case of urban roads in Portugal, the speeds change frequently and therefore, that drivers might select higher speeds also as a way not to be constantly changing the speed in the system (action that might be considered annoying since the driver has to press the button some times).

- Avoid the engagement into secondary tasks while the systems are active

Drivers should be informed about the real danger to road safety that they cause when they perform other task while the system is active: this can be done via information and campaigns that alert about this issue. However, the vehicle could also have some barriers to avoid this type of situations; for example if the mobile phone was, somehow, synchronized with the vehicle, calls could be blocked at times that the driver is driving with the systems active. It should be noticed, anyway, that this last measure could be somehow hard to implement since it is very restrictive.

FINAL CONSIDERATIONS

Being a survey, the main limitation of this study resides in the fact that the results are purely based on the opinions of the drivers and this type of data is subjective.

The questionnaire size might have been the reason for some questions' high rate of non-answers: most probably, people got tired of answering to all the questions. Another limitation was the reduced number of respondents in the older drivers' age groups compared to the other age groups: therefore, the results obtained for this age group of drivers should be seen with some caution.

Taking the experience of this study as a basis, some aspects could be improved in a next similar study. The first aspect is the size of questionnaire, which should be reduced, then the distribution of the age groups of the sample should be more homogeneous. Finally, the interviews should be applied to a bigger sample.

As perspective for future investigations, the results from the questionnaire can be compared to the findings obtained during the naturalistic driving study (that has been just completed). It would also be interesting to understand, in future studies, how the level of experience, acceptance, mental model and the trust of the system influences drivers engagement in secondary tasks.

CONCLUSION

There were no previous studies performed in Portugal about how drivers perceive the use of speed regulating systems, more specifically the CC and the SL. Considering that speed regulating systems are already available in a considerable part of the national car park, it was important to understand how drivers really perceive their effect on the driving task. In terms of road safety, this perception gives crucial information to understand the needs and the measures that could improve road safety.

The CC most recognized benefits were the comfort (reported in 38.5% of the answers), followed by helping to control the speed (32% of the answers). The SL is clearly considered as a system that aims to help drivers to control the speed (61.1%).

According to drivers' reports, for both systems, most of the times, drivers select speeds that are equal to the legal speed limit, which means that these systems have the potential to favour speed compliance and, consequently, road safety. The SL users are driving less frequently above the legal limits when compared to the CC and this can be explained by the specific aim of each system (and also confirmed by the results expressed by the sample in the perceived benefits): the SL is a system that helps the driver to control the speed whereas the CC is a system that enhances comfort.

It was found a statistical relation between the speed selected in the CC and the gender: while driving with the CC activated it seems that more females are keeping the speed according to the legal speed limit, whereas more males choose to travel at speeds higher than the legal speed limit. This finding can be explained by the fact that females tend to disregard less the speed limits and the other traffic rules when compared to males.

It was also found that while using the CC, drivers engage into secondary tasks but, the same was not found for the SL. However, this result should be further investigated since it is not possible to generalize, since from the questionnaire, there was a high rate of non-answers, and this conclusion came basically from two interviews with experienced CC users.

It was not statistically confirmed the relation between age category and frequency of use of both speed regulating systems (CC and SL). However, younger drivers seem to be less prone to use the speed regulating systems than middle aged and older drivers.

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APPENDICES

APPENDIX I: Interview guide

1. In these situations, do you remember which was the reason that made you use the mobile phone when the cruise control was active?

   1.1 Was it intentional or not?

2. Do you think that when the cruise control is active the driver is more available to engage into other tasks?

   2.1 If yes, do you usually perform other tasks with the cruise control activated?

   2.2 What kind of secondary tasks do you perform?

3. Did you ever activate the cruise control to focus on another task that not driving task?

4. Did you ever feel monotony while driving with the cruise control activated?

   4.1 Which of these two factors do you consider to have a greater impact on the monotony of the driving task, the cruise control or the road environment?

   4.2 What do you do when you feel monotony? (Turn the cruise control off, make a phone call, touching the radio, etc...)

   4.3 Did you ever engage into a secondary task to compensate the monotony of driving with the cruise control active?

5. Since you drive a vehicle equipped with the cruise control, do you think that your predisposition to engage into secondary tasks increased? (phone calls, programming the navigation system, etc.)

6. Did you ever activate the speed limiter to focus on another task that not the driving task?

ANNEXES

BACKGROUND QUESTIONS

Q7. Are you:

Q7A. □ Male

Q7B. □ Female

Q8. How old are you? _______ years

Q9. How many people (apart from you) live in your household?

Q9A. number of adults _____

Q9B. number of children (under 18) _____

Q10. Were you born in the country where you currently live?

Q10A. □ yes

Q10B. □ no. In which country were you born? ______________________

Q11. Do you have a driving licence which was issued in the country where you currently live?

Q11A. □ yes

Q11B. □ no.

Q11B1. In which country did you obtain your driving licence?

____

Q12. What is your highest level of education?

Q12A. □ Compulsory school
Q12B. □ Upper secondary school
Q12C. □ University
Q12D. □ None of the above

Q13. What is your occupation?

Q13A. □ Student
Q13B. □ Full-time work
Q13C. □ Part-time work
Q13D. □ Parental leave
Q13E. □ Retired
Q13F. □ Unemployed
Q13G. □ Other (military service, homemaker, leave of absence etc.)

QUESTIONS ABOUT DRIVING

Q14. On average, how many kilometres (miles for UK) do you drive over a 12 month period?

Q14A. □ under 5 000 km (3000 miles)
Q14B. □ 5 000 – 9 999 km (3000 - 5999 miles)
Q14C. □ 10 000 – 19 999 km (6000 – 11 999 miles)
Q14D. □ 20 000 – 29 999 km (12000-18 999 miles)
Q14E. □ over 30 000 km (19000 miles)

Q15. 10. On average, how many hours do you drive in a normal week?
________________hour(s)

Q16. How many cars do you drive regularly? ______

Q17. Is this vehicle owned by...?

Q17A. □ Yourself
Q17B. □ Another member of your family
Q17C. □ Your employer/or rented by your employer
Q17D. □ A hire or leasing company
Q17E. □ other (please specify ________________________)

Q18. How old is this vehicle ? _______ years

Q19. Make and model of this car __________________________

Q20. Is this car

Q20A. □□ manual
Q20B. □ □automatic

Q21. Do you use this car for business or professional matters (other than for commuting)?

Q21A. □□ yes
Q21B □ no

Q22. Are you a professional driver (e.g. taxi driver, bus driver,…?) ?
Q22A. □□ no
Q22B. □ □yes,

Q22B1. please specify _____________
Q22B2. Since when have you worked as a professional driver? since: ____________ (year)

Q23. How often do you drive on the following types of road?

	Frequently (at least once a day)	Regularly (at least once a week)	Occasionally (at least once a month)	Rarely (at least once a year)	Never
Q23A. Motorways					
Q23B. Main roads and rural roads					

Q23C. City roads					
Q23D. Familiar roads					
Q23E Unfamiliar roads					

QUESTIONS ABOUT CRUISE CONTROL

Q24. Since when have you had a Cruise Control system?

since: ____________________ year(s)

Q25. Is your system :

Q25A. □ a Cruise Control (CC), which maintains the speed of the car to a selected constant value, or
Q25B □ an Adaptive Cruise Control (ACC), which also reduces the vehicle's speed to keep a safe distance to the cars in front?

Q26. How often do you use Cruise Control?

Q26A. □ Frequently (*at least once a day)*
Q26B. □ Regularly (*at least once a week*)
Q26C. □ Occasionally (*at least once a month*)
Q26D. □ Rarely (*at least once a year*)
Q26E. □ Never

Q27. From your point of view, what are the main benefits of Cruise Control?
(Please put the three main benefits for you in order: 1= most important, 2 = second important, 3 = third important)

Q27A. It helps to control speed	
Q27B. It helps to reduce speeding	
Q27C. It improves the safety of driving	
Q27D. It improves the comfort of driving	
Q27E. It reduces fuel consumption	
Q27F. Other (please specify)	

Q28. Here is a list of different situations in which Cruise Control can be used. Please consider the usefulness of Cruise Control in these situations and rate each of the alternatives on a scale from 0to 5, where 0 = not useful at all and 5 = very useful.

When I'm driving….
Q28A… on motorways 0 1 2 3 4 5
I don't know
Q28B… on main roads and rural roads 0 1 2 3 4 5
Q28C.… on city roads 0 1 2 3 4 5

When I'm driving…
Q28D… in familiar environments 0 1 2 3 4 5
Q28E… in unfamiliar environments 0 1 2 3 4 5

Q28F When there are speed checks	0	1	2	3	4	5
Q28G When the police are not around	0	1	2	3	4	5
Q28H When I'm commuting	0	1	2	3	4	5
Q28I During business trips	0	1	2	3	4	5
Q28J During private trips	0	1	2	3	4	5
Q28K During short trips	0	1	2	3	4	5
Q28 L During long trips	0	1	2	3	4	5
When I'm driving…						
Q28M … in light traffic conditions	0	1	2	3	4	5
Q28N … in heavy traffic conditions	0	1	2	3	4	5
Q28O… in a traffic jam (stationary traffic)	0	1	2	3	4	5
Q28P … in areas with road works	0	1	2	3	4	5
Q28Q… on roads where there are special warnings (animals, sharp bends, children, etc.)	0	1	2	3	4	5
Q28R When I want to reduce my workload	0	1	2	3	4	5
Q28S When I want to concentrate on other things	0	1	2	3	4	5
Q28T When I'm driving alone	0	1	2	3	4	5
Q28U When I have passengers	0	1	2	3	4	5
Q28V When I'm tired	0	1	2	3	4	5
Q28W When I'm lost	0	1	2	3	4	5
Q28X When I'm driving during daytime	0	1	2	3	4	5
Q28Y When I'm driving at night-time	0	1	2	3	4	5
Q28Z When the weather conditions are clear	0	1	2	3	4	5
Q28ZZ When the weather conditions are poor	0	1	2	3	4	5

Q29. On average, how much do you use the Cruise Control system while driving?

Q29A □ For the entire journey

Q29B □ For more than half of the journey

Q29C □ For about half of the journey

Q29D □ For less than half of the journey

Q29E □ Never

Q29F □ I don't know

Q30. How do you position your feet when you are using Cruise Control?

Q30A. □ near the pedals
Q30B. □ far from the pedals
Q30C. □ feet crossed
Q30D. □ I don't know

Q31. Generally, how do you select the speed when you are using Cruise Control?
Q31A. □ Below the legal speed limit
Q31B. □ Equal to the legal speed limit
Q31C. □ Above the legal speed limit

Q32. If the selected speed is different from the legal speed limit, please indicate the difference in kilometres: _______________ km/h

Q33. What are your opinions about the Cruise Control system? For each statement, please choose between the alternatives ranging from “strongly agree” to “strongly disagree”:

Cruise Control system…	strongly agree	agree	disagree	strongly disagree	I don’t know
Q33A. is useful					
Q33B. is easy to use					
Q33C. functions logically					
Q33D. functions faultlessly					
Q33E. helps to maintain constant speed					
Q33F. makes driving easier					
Q33G. makes it easier to concentrate on driving					
Q33H. allows the driver to regain easily the control of the car by pressing pedals					
Q33I. causes driver distraction					
Q33J. makes driving monotonous					
Q33K. modifies driver posture inside the car (foot position)					
Q33L. increases braking time					
Q33M. reduces conflicts in traffic situations					
Q33N. takes control of the car away from the driver					
Q33O. makes drivers feel protected or safe					
Q33P. reduces fuel consumption					
Q33Q. is					

expensive					
Q33R. is unreliable					
Q33S. I am satisfied with the functioning of Cruise Control					
Q33T. I would like to have Cruise Control in my next car					
Q33U. I would recommend Cruise Control to a friend					
Q33V. It is difficult to understand how Cruise Control works					
Q33W. Cars are safe enough without systems like Cruise Control					
Q33X. Other (please specify) ______________					

QUESTIONS ABOUT SPEED LIMITER

Q34.. Since when have you had a Speed Limiter system?

since: ________________________ year(s)

Q35. From your point of view, what are the main benefits of Speed Limiter?
(Please put the three main benefits for you in order: 1= most important, 2 = second important, 3 = third important.)

Q35A. It helps to control speed	
Q35B. It helps to reduce speeding	
Q35C. It improves the safety of driving	
Q35D. It improves the comfort of driving	
Q35E. It reduces fuel consumption	
Q35F. Other (please specify)	

Q36. How often do you use Speed Limiter?

Q36A. □ Frequently (*at least once a day)*
Q36B. □ Regularly (*at least once a week*)
Q36C. □ Occasionally (*at least once a month*)
Q36D. □ Rarely (*at least once a year*)
Q36E. □ Never

Q37. Here is a list of different situations in which Speed Limiter can be used. . Please consider the usefulness of Speed Limiter in these situations and rate each of the alternatives on a scale from 0 to 5, where 0 = not useful at all and 5 = very useful.

When I'm driving…						
Q37A… on motorways	0	1	2	3	4	5
Q37B… on main roads and rural roads	0	1	2	3	4	5
Q37C… on city roads	0	1	2	3	4	5
When I'm driving…						
Q37D… in familiar environments	0	1	2	3	4	5
Q37E… in unfamiliar environments	0	1	2	3	4	5
Q37F. When there are speed checks	0	1	2	3	4	5
Q37G. When the police are not around	0	1	2	3	4	5
Q37H. When I'm commuting	0	1	2	3	4	5
Q37I During business trips	0	1	2	3	4	5
Q37J. During private trips	0	1	2	3	4	5
Q37K .During short trips	0	1	2	3	4	5
Q37L. During long trips	0	1	2	3	4	5
When I'm driving…						
Q37M… in light traffic conditions	0	1	2	3	4	5
Q37N… in heavy traffic conditions	0	1	2	3	4	5
Q37O… in a traffic jam (stationary traffic)	0	1	2	3	4	5
Q37P… in areas with road works	0	1	2	3	4	5
Q37Q… on roads where there are special warnings (animals, sharp bends, children, etc.)	0	1	2	3	4	5
Q37R When I want to reduce my workload	0	1	2	3	4	5
Q37S When I want to concentrate on other things	0	1	2	3	4	5
Q37T. when I'm driving alone	0	1	2	3	4	5
Q37U. when I have passengers	0	1	2	3	4	5
Q37V. when I'm tired	0	1	2	3	4	5
Q37W when I'm lost	0	1	2	3	4	5
Q37X. When I'm driving during daytime	0	1	2	3	4	5
Q37Y. When I'm driving at night-time	0	1	2	3	4	5
Q37Z. When the weather conditions are clear	0	1	2	3	4	5
Q37ZZ. When the weather conditions are poor	0	1	2	3	4	5

Q38. On average, how much do you use the Speed Limiter system while driving?

Q38A ☐ For the entire journey

Q38B ☐ For more than half of the journey

Q38C ☐ For about half of the journey

Q38D ☐ For less than half of the journey

Q38E ☐ Never

Q38F ☐ I don't know

Q39. Generally, how do you select the speed when you are using the Speed Limiter?

Q39A. ☐ Below the legal speed limit
Q39B. ☐ Equal to the legal speed limit

Q39C. □ Above the legal speed limit

Q40. If the selected speed is different from the legal speed limit, please indicate the difference in kilometres:_______________ km/h

Q41. What are your opinions about the Speed Limiter ? For each statement, please choose between the alternatives ranging from “strongly agree” to “strongly disagree”:

Speed Limiter system…	strongly agree	agree	disagree	strongly disagree	I don’t know
Q41A. is useful					
Q41B. is easy to use					
Q41C. functions logically					
Q41D. functions faultlessly					
Q41E. makes driving easier					
Q41F. makes it easier to concentrate on driving					
Q41G. allows the driver to override the speed limit selected easily					
Q41H. causes driver distraction					
Q41I. makes driving monotonous					
Q41J. reduces conflicts in traffic situations					
Q41K. takes control of the car away from the driver					
Q41L. makes drivers feel protected or safe					
Q41M. reduces fuel consumption					
Q41N. is expensive					
Q41O. is unreliable					
Q41P I am satisfied with the functioning of					

the Speed Limiter					
Q41Q. I would like to have a Speed Limiter in my next car					
Q41R. I would recommend a Speed Limiter to a friend					
Q41S. It is difficult to understand how a Speed Limiter works					
Q41T. Cars are safe enough without systems like Speed Limiters					
Q41U. Other (please specify) ______________					